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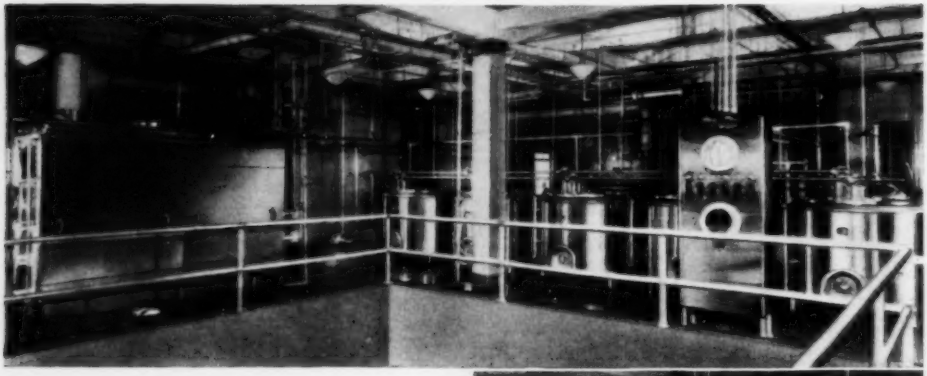

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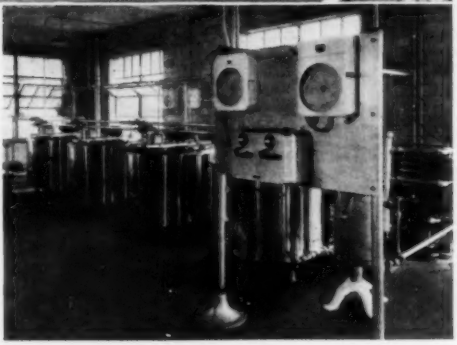

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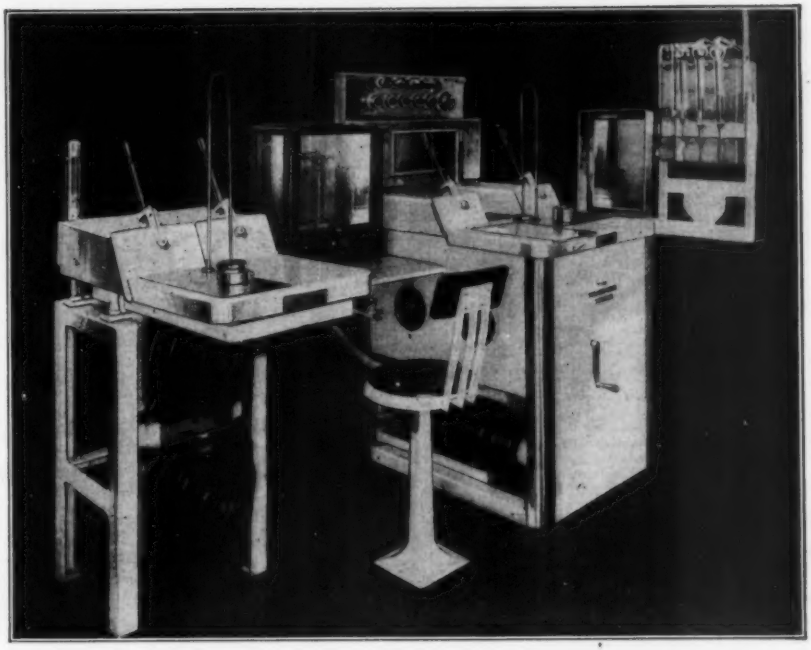

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JOURNAL OF DAIRY SCIENCE

VOLUME XIX JANUARY, 1936 NUMBER 1

THE EFFECT OF PROCESS OF MANUFACTURE ON THE VITAMIN G CONTENT OF DRIED SKIM MILK

H. J. DAVIS AND L. C. NORRIS

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The value of milk in promoting the growth of animals has long been recognized. In general this has been thought to be due to the completeness of milk in the essential nutritive elements and to their excellent balance. This is obviously true in the case of young animals depending largely, or entirely, on milk for their food supply.

However, in the case of animals fed small quantities of milk as a supplement to a ration adequate in all respects except that it does not promote rapid growth this explanation is unsatisfactory. This applies particularly to poultry to which have been fed enormously increasing quantities of skim milk and buttermilk during the past 20 years as a supplement to rations composed of cereals, cereal by-products and meat by-products in order to obtain rapid growth of chicks and good hatchability of eggs. The most usual explanation of these good effects was that the proteins of milk when combined with the cereal and meat proteins improved the quality of the resulting protein mixture and thereby favorably influenced growth and hatchability.

Recently Norris and his coworkers (1, 2) and Bethke and his associates (3) have shown that vitamin G is of great practical importance in the nutrition of poultry and that one of the chief values of milk for feeding this species is due to its vitamin G content. Furthermore, a study of present-day poultry rations shows that milk by-products supply a large part of the vitamin G present in them. In view of this the question of the partial destruction of vitamin G in milk by-products becomes an exceedingly important one, since much of the milk used in feeding poultry is in the dried form. Therefore an investigation was undertaken to determine whether or not any destruction of this vitamin occurs during the drying process.

Under certain conditions vitamin G is subject to destruction by heat, although it is frequently described as being relatively heat stable. In 1927 Chick and Roscoe (4) found that by autoclaving brewer's yeast at 120° C. for five hours at its normal pH (pH 4.5–5.0), approximately one-half of the

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original vitamin G content was destroyed. Williams, Waterman and Gurin (5) later repeated this work and varied the pH from 1.6 to 14.0. Here it was also found that, when the pH was held about normal, five hours heating at a temperature of 120° C. destroyed around 50 per cent of the vitamin G originally present. If the reaction was made more acid, there was less destruction of vitamin G. However, when the pH was increased there was a corresponding increase in the amount of vitamin G destroyed.

A somewhat similar study in which protein-free milk was heated in a water bath at 97° C. for different lengths of time at varying H-ion concentrations was reported by Halliday (6) in 1932. The results of this study demonstrated that heating for one hour caused a 25 per cent loss of vitamin G at pH 4.3, 30 per cent at pH 7.0, and 70 to 80 per cent at pH 10.0. Heating for four hours caused a 30 to 40 per cent loss at pH 4.3, 40 per cent at pH 7.0, and almost complete destruction at pH 10.0. Holding the milk in cold storage for one week caused practically no loss at pH 4.3 or pH 7.0 but nearly complete loss at pH 10.0.

In 1933 Krauss, Erb and Washburn (7) reported studies of the effect of pasteurization upon some of the nutritive properties of milk and found that commercial pasteurization (heating to 143°–144° F. for 30 minutes) did not destroy any of the vitamin G contained in the raw milk. More recently Dutcher, Guerrant and McKelvey (8) studied the effect of various methods of pasteurization on the vitamin B and G content of milk. The samples used in this work were not pasteurized by means of commercial equipment, but were prepared in the laboratory in such a way as to be comparable to different methods of pasteurization. The heat treatments studied were as follows: (1) ordinary pasteurization, (2) pasteurization under reduced pressure, (3) pasteurization with aeration, and (4) boiling for ten minutes. It was found that some loss of vitamin G occurred in all methods of pasteurization studied but less destruction occurred when the milk was boiled for 10 minutes under a reflux condenser.

The investigation reported in this paper included a study of the effects of drying skim milk under normal conditions by the Merrell-Soule spray process, the Gray-Jensen spray process and the open-roller process, complete descriptions of which are given by Hunziker (9). Since most of the dried milk is manufactured by these three methods, it was not considered necessary to make a study of other processes. In addition to this work studies were made of the effects of extreme manufacturing conditions upon the vitamin G content of the skim milk.

In 1934 György (10) reported results, obtained in studies with the rat, which showed that vitamin B_2 (G) consisted of two components. One of these, designated vitamin B_6, prevented a pellagra-like dermatitis and the other, lactoflavin, was necessary for growth. Ringrose and Norris (11) also in 1934 presented evidence obtained in studies with the chick, showing that

vitamin G was a complex composed of an essentially growth-promoting component and another component which prevented a pellagra-like syndrome. Similar findings have been reported more recently by Chick, Copping and Edgar (12). The work reported in this paper deals primarily with the growth-promoting component of the vitamin G complex.

EXPERIMENTAL PROCEDURE AND RESULTS

In studying the effect of manufacturing process on the vitamin G content of skim milk, dried skim milk was compared with the liquid skim milk for relative vitamin G potency. Fresh samples of milk were received daily by special delivery from near-by plants. The liquid milk was shipped cold in chilled vacuum bottles and the dried milk in friction top cans. The samples of dried skim milk were prepared from the same tank of skim milk as the liquid milk samples in order to be sure that both samples possessed the same original vitamin G potency.

The pens of chicks receiving liquid skim milk were fed so that the average consumption of milk solids per chick was the same as that of the complementary pens receiving dried skim milk. This was accomplished by determining the dry matter content of the liquid skim milk, and then calculating the exact amount of liquid skim milk necessary to furnish milk solids equivalent to those contained in a definite amount of dried skim milk. In preliminary experiments it was found necessary to remove the drinking water from the pens receiving liquid skim milk as soon as the milk was fed in order to induce the chicks to drink the milk quickly. This raised the question of whether or not this procedure would interfere with water consumption. In order to avoid introducing another variable the dried skim milk was reconstituted to approximately its original concentration and fed in a liquid form. Throughout each experiment special precautions were taken to see that the milk did not sour before it was consumed.

In all of this work the Cornell strain of Single Comb White Leghorn chicks was used. These chicks were fed a vitamin G deficient ration for the first two weeks after hatching so as to deplete their body reserve of vitamin G. At the end of this time chicks of approximately average weight were selected and evenly distributed in the required number of pens of 25 chicks each. Each chick was weighed individually at weekly intervals for a period of six weeks following the depletion period.

The basal ration used and the method of adding milk are shown in Table 1. The feed ingredients were analyzed for protein and moisture and combined in such a way that the protein content of each ration was 22 per cent, air dry basis. Casein purified of vitamin G was used as the only source of protein aside from that contained in the cereal portion of the ration. To this basal ration were added graded amounts of the different forms of milk as shown in Table 1. In making the milk additions, the protein level was

maintained constant by making the necessary adjustments in the amount of purified casein and corn meal in the basal ration. In each experiment, pen 1 received the basal ration only and the last pen received the basal ration plus 12.5 per cent of dried skim milk. These pens were designated as negative and positive controls, respectively. The intermediate pens received comparable amounts of the samples of milk being studied.

TABLE 1
Basal ration and method of adding milk

INGREDIENTS	PEN							
	1	2	3	4	5	6	7	8
	%	%	%	%	%	%	%	%
Yellow corn meal	61.2	59.5	59.5	57.8	57.8	56.1	56.1	52.6
Wheat flour middlings	20.0							
Pulverized limestone	2.0							
Steamed bone meal	1.0			Same as pen 1				
Cod liver oil	1.0							
Salt	0.5							
Purified casein	14.3	13.5	13.5	12.7	12.7	11.9	11.9	10.4
Dried skim milk	.....	2.5	.....	5.0	.....	7.5	.....	12.5
Liquid skim milk (dry basis)	.....	.....	2.5	.....	5.0	.....	7.5	.....
Protein (air dry basis)	22.02	22.01	22.01	22.00	22.00	22.01	22.01	22.01

The data obtained were analyzed by the method of "weighted squares of means" of Titus and Hammond (13) in order to determine whether or not the growth differences were statistically significant. The degree of significance of the t values were taken from Snedecor's table giving values of F and t (14).

In Tables 2, 3, and 4 are presented results of the experiments in which dried skim milk, manufactured by the Merrell-Soule spray process, the Gray-Jensen spray process and the open-roller process were compared with fresh liquid skim milk for vitamin G potency. In each experiment the comparable pens receiving 2.5 and 5 per cent of skim milk showed only slight differences in weight at the end of the experimental period, the t value being less than 1.97 in each case, the value necessary for significance. In the pens receiving 7.5 per cent of skim milk there was more variation in growth than at the lower levels, but this difference was not statistically significant in any experiment. In the data presented it will be noted that there is a consistent increase in the value of t with increasing amounts of milk. This apparently cannot be explained as being due to increasing amounts of milk because in other experiments, the data of which are not included in this paper, the reverse was found to be true.

TABLE 2

The effect of drying by the Merrell-Soule spray process on the vitamin G content of skim milk

PEN	RATION	AVE. WT. AT 8 WKS.	t*
		gm.	
1	Negative control	258.1	
2	2.5% dried skim milk	427.3	0.269
3	2.5% liquid skim milk	420.5	
4	5.0% dried skim milk	500.4	0.699
5	5.0% liquid skim milk	484.0	
6	7.5% dried skim milk	529.0	1.221
7	7.5% liquid skim milk	560.4	
8	12.5% dried skim milk	568.6	

* Whenever $t = 1.972$ (odds 19: 1) the results are significant statistically; whenever $t = 2.601$ (odds 99: 1) results are highly significant statistically.

Since the positive control pens receiving 12.5 per cent of skim milk were only slightly heavier than the pens receiving 7.5 per cent of skim milk, it was evident that with the basal ration used in this work 7.5 per cent of skim milk furnished enough vitamin G to afford nearly optimum growth. This made it impossible in drawing conclusions to give much consideration to the pens receiving 7.5 per cent of skim milk. Therefore, basing conclusions on the statistical analysis of the results of replicate pens receiving 2.5 and 5.0

TABLE 3

The effect of drying by the Gray-Jensen spray process on the vitamin G content of skim milk

PEN	RATION	AVE. WT. AT 8 WKS.	t*
		gm.	
1	Negative control	230.9	
2	2.5% dried skim milk	358.7	0.034
3	2.5% liquid skim milk	357.9	
4	5.0% dried skim milk	432.7	0.423
5	5.0% liquid skim milk	442.7	
6	7.5% dried skim milk	455.9	1.194
7	7.5% liquid skim milk	482.7	
8	12.5% dried skim milk	506.2	

* Whenever $t = 1.968$ (odds 19: 1) the results are significant statistically; whenever $t = 2.592$ (odds 99: 1) results are highly significant statistically.

TABLE 4

The effect of drying by the open-roller process on the vitamin G content of skim milk

PEN	RATION	AVE. WT. AT 8 WKS.	t*
		gm.	
1	Negative control	230.9	
2	2.5% dried skim milk	364.6	0.280
3	2.5% liquid skim milk	357.9	
4	5.0% dried skim milk	421.2	0.870
5	5.0% liquid skim milk	442.8	
6	7.5% dried skim milk	459.4	1.061
7	7.5% liquid skim milk	482.3	
8	12.5% dried skim milk	506.2	

* Whenever $t = 1.972$ (odds 19 : 1) the results are significant statistically; whenever $t = 2.601$ (odds 99 : 1) results are highly significant statistically.

per cent of skim milk, it is obvious that there was no measurable destruction in the vitamin G content of skim milk when manufactured by either the Merrell-Soule spray process, the Gray-Jensen spray process or the open-roller process.

The studies of the effect of extreme manufacturing methods on the vitamin G content of dried skim milk included the effect of holding liquid skim milk in storage tanks at a moderately high temperature previous to drying, the effect of scorching skim milk during the manufacturing process and the effect of adjusting the pH of sour skim milk to various degrees of acidity and alkalinity. Comparable samples of milk were taken from the same tank of liquid skim milk and dried by the same process.

In determining the effect of holding liquid skim milk in storage tanks at a relatively high temperature, special samples of milk were prepared by heating one large tank of liquid skim milk to 170° F. and drying small quantities of milk from this tank at intervals of 6, 12, 18 and 24 hours. During the last 6 hours of storage the temperature dropped (inadvertently) from 170° F. to 120° F.

The results of this experiment are presented in Table 5. Pen 2 receiving 5 per cent of skim milk, dried previous to heating the tank of milk, was taken as a standard for comparison. The statistical analysis of these data showed that no destruction of vitamin G occurred as a result of pre-heating liquid skim milk at 170° F. for a period of 18 to 24 hours.

Table 6 gives the results of a study to determine the effect on the vitamin G content of varying the drying temperature and of scorching skim milk during the drying process. Pen 2 received choice grade roller process dried skim milk which is representative of the product manufactured in commer-

TABLE 5

The effect of storage at a relatively high temperature on the vitamin G content of skim milk

PEN	RATION	AVE. WT. AT 8 WKS.	t*
		gm.	
1	Negative control	234.4	
2	5% spray process dried skim milk not stored previous to drying	424.2	
3	5% spray process dried skim milk stored 6 hrs. at 170° F. previous to drying	428.8	0.172
4	5% spray process dried skim milk stored 12 hrs. at 170° F. previous to drying	404.5	0.682
5	5% spray process dried skim milk stored 18 hrs. at 170° F. previous to drying	418.6	0.210
6	5% spray process dried skim milk stored 24 hrs. at 170° F. previous to drying**	425.5	0.046
7	12.5% dried skim milk	512.4	

* Whenever $t = 1.968$ (odds 19:1) the results are significant statistically; whenever $t = 2.592$ (odds 99:1) results are highly significant statistically.

** During the last 6 hrs. of storage the temperature dropped from 170° F. to 120° F..

cial practice. The steam pressure within the rolls used in drying this sample was approximately 90 pounds per square inch. Pen 3 received roller process dried skim milk, made by reducing the steam pressure to 50 pounds per square inch, and then adjusting the rolls so that a thinner film of milk

TABLE 6

The effect of varying the drying temperature on the vitamin G content of skim milk

PEN	RATION	AVE. WT. AT 8 WKS.	t*
		gm.	
1	Negative control	258.1	
2	5% roller process dried skim milk—choice grade	520.0	
3	5% roller process dried skim milk—50 lbs. pressure	491.8	1.061
4	5% roller process dried skim milk—slightly scorched	528.9	0.366
5	5% roller process dried skim milk—scorched	500.4	0.782
6	12.5% dried skim milk	568.6	

* Whenever $t = 1.972$ (odds 19:1) the results are significant statistically; whenever $t = 2.601$ (odds 99:1) results are highly significant statistically.

was applied. The light scorched roller process dried skim milk was prepared by leaving the rolls adjusted the same as for the previous sample and increasing the steam pressure to 100 pounds per square inch. The scorched roller process dried skim milk was made by adjusting the rolls the same as for the light scorched sample and raising the knives at definite intervals. This allowed the milk to remain on the rolls for two revolutions before lowering the knives and scraping it off. The statistical analysis of the data showed that there was no significant difference in the vitamin G potency of the different samples studied.

Special samples of milk were prepared in such a way as to measure the effects of souring, of partially or completely neutralizing sour milk and of making the milk alkaline, as shown in Table 7. Pen 2 received dried skim

TABLE 7

The effect of acid and alkali on the vitamin G content of skim milk

PEN	RATION	AVE. WT. AT 8 WKS.	t*
		gm.	
1	Negative control	234.4	
2	5% roller process dried skim milk—0.14% acidity (normal)	445.3	
3	5% roller process dried skim milk—soured to 0.21% acidity	431.8	0.511
4	5% roller process dried skim milk—soured to 0.28% acidity, then neutralized with lime to 0.035% acidity	421.3	0.881
5	5% roller process dried skim milk—soured to 0.39% acidity, then neutralized with lime to 0.03% alkalinity	431.2	0.504
6	5% roller process dried skim milk—soured to 0.39% acidity, then neutralized with lime to 0.15% alkalinity	409.8	1.318
7	5% roller process dried skim milk—soured to 0.39% acidity, then neutralized with $NaHCO_3$	424.0	0.800
8	5% roller process dried skim milk—soured to 0.24% acidity, then neutralized with lime to 0.015% alkalinity	457.0	0.370
9	5% roller process dried skim milk—soured to 0.24% acidity, then neutralized with lime to 0.065% alkalinity	422.4	0.851
10	12.5% dried skim milk	512.4	

* Whenever $t = 1.968$ (odds 19:1) the results are significant statistically; whenever $t = 2.592$ (odds 99:1) results are highly significant statistically.

milk testing 0.14 per cent titratable acidity, the normal acidity of fresh milk. The next four pens (pens 3 to 6 inclusive) received milk which had partially soured and then had the H-ion concentration adjusted by adding the necessary amount of hydrated lime. In pen 7 the milk was soured as in pens 5 and 6 and neutralized with sodium bicarbonate instead of lime.

The statistical analysis of the results of this experiment, with the possible exception of pen 6 which received dried skim milk previously soured and then made alkaline (0.15 per cent titratable alkalinity), showed that all samples possessed approximately the same vitamin G potency. When this experiment was repeated, pen 6 which received the same milk as in the previous experiment again gave poorer results than any of the other samples. Upon combining the results of these two experiments, this difference was not found to be statistically significant. However, it does appear to be of some biological significance. These findings are not entirely in agreement with the work previously mentioned by Halliday (5). This discrepancy is probably due to the difference in the vitamin G carrier used. Halliday worked with protein-free milk, and in removing the proteins from the milk the stability of vitamin G was probably affected so as to make it more readily destroyed by heat and alkali.

CONCLUSIONS

The results of this investigation show that there was no significant destruction of the growth-promoting component of the vitamin G complex contained in skim milk when dried by the Merrell-Soule spray process, the Gray-Jensen spray process or the open-roller process.

Also no measurable destruction of vitamin G occurred as a result of holding liquid skim milk in storage tanks at 170° F. for 18 to 24 hours previous to drying, or of slightly scorching the milk powder during the drying process, or of neutralizing sour skim milk previous to drying. However, when sufficient alkali was added to bring the pH to approximately 9.5 or the titratable alkalinity to 0.15 per cent a slight destruction of vitamin G appeared to take place.

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THE EFFECT OF FLIES AND FLY SPRAYS ON CERTAIN PHYSIOLOGICAL PROCESSES OF THE DAIRY COW

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Although nearly 30 years have elapsed since it was first demonstrated that the production of dairy cows is not lessened by their exposure to flies, and that the use of fly repellents cannot be justified on economic grounds (1, 2, 3) dairymen are still spending, in the aggregate, vast sums of money for commercial animal sprays. Judged by the increasing number of requests received by the College of Agriculture for information on the subject, the use of fly sprays in California, at least has increased rather than diminished in recent years.

This growing interest in the problem, the improved specialized research equipment available at this station (including a psychrometric room and a respiration chamber, both large enough to accommodate two mature cows) and the general scientific knowledge that has been developed since the original researches were conducted 30 years ago, all seemed to warrant a reinvestigation of flies and fly sprays in their relation to dairy cows.

The work reported herein was begun in 1925. Four papers (10, 11, 12, 13) written primarily from the standpoint of entomological interest have been published. The study involves a consideration of (1) the effect of flies on the cow, (2) the effect of sprays on the flies and (3) the effect of sprays on the cows. The first two have been rather thoroughly investigated. Several careful workers (1, 2, 3, 4) conclude that flies cause little or no loss in production, while Bishopp (9) cites a loss of from 40 to 60 per cent in milk flow during a severe outbreak of stable flies. Certain sprays were found to be effective in repelling flies for but an hour or two, while others protected the animals for 24 hours or more. Previous to the time this experiment began, no one had attempted to determine, by controlled experiments, the effect of fly sprays upon the health and production of the animals. In those trials that have been run, no attempt was made to establish extreme conditions. Experimental animals, chosen without special regard to productive ability, were exposed to whatever flies happened to be available, and production compared to that of the same or other cows, when protected, either by repellent sprays or screened stalls. None of the infestations was extremely heavy, a fact that might explain the disagreement between their findings and the report of Bishopp mentioned above. In our work we used high producing cows, exposing them to attack by great numbers of each of three different species of flies in pure cultures.

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FLIES USED

House Fly (*Musca domestica* L.).—Of the three species studied, this is usually the most numerous inside the dairy barn. Possessed of non-biting mouth parts, it depends upon exposed foods, liquid or semi-liquid, and therefore probably annoys the cattle only through walking about on their bodies.

Stable Fly (*Stomoxys calcitrans* L.).—The adults are not particularly noticeable, as they do not congregate on the animals and do not differ strikingly in appearance from the house fly. The stable fly spends most of its life hidden away on the walls of buildings or on vegetation and comes to the animals for its meal of blood approximately once a day, generally in the morning. The favorite point of attack is the legs or underline. The stable fly fed in the laboratory required approximately nine minutes to secure an average meal of 15 milligrams of blood, an astonishingly large amount when it is noted that the average body weight before feeding was 7.4 milligrams. On exceedingly hot days, when the temperature was above 100° F., the stable flies fed twice daily, once in the early morning and again in the late afternoon.

Horn Fly (*Lyperosia irritans* L.).—This insect is probably the most noticeable fly that annoys cattle and for that reason its importance is probably overestimated. In laboratory trials we have never been able to make this species bite more than once a day, the average meal consisting of 3.2 milligrams of blood. It is not a serious pest in the interior valleys of California. During June, July, and August, the condition of high temperature and low humidity, not only dries out the natural breeding places but is intolerable to the adults. The coastal counties, however, with their higher humidity and cooler days, offer a more suitable habitat.

METHOD OF SECURING FLIES

The initial cultures of the stable fly and the house fly were from bred material. The house flies were reared by packing maggot infested manure into cylindrical wire baskets, which were then placed in 10-gallon crocks, the bottoms of which were covered with sand. As the larvae matured they migrated from the baskets, falling into the crocks and proceeded to pupate in the sand. The pupae were then held in cold storage at 7° C. until a few days before needed.

The stable flies were bred in this manner to a limited degree only, as their larvae had a tendency to migrate out of the baskets before maturity. A more successful procedure was to allow them to come to maturity in stout wooden boxes filled with manure and capture the adults in conical traps as they sought the light. It was possible to collect almost pure cultures of stable fly larvae, the only contaminating flies being *Muscina stabulans* Fallen and *Eristalis temax* L.

Owing to the difficulty in handling sufficient manure to insure a large number of horn flies,—those breeding in a single deposition of cow manure being insignificant compared to the number required,—it was decided to gather them by sweeping with a net from the backs of cattle. Later in the experiment, we obtained in pure cultures stable flies by sweeping the inside walls of the barn, and house flies by trapping.

To determine the numbers used, the flies were blown against the walls of a screen cage with an electric fan where they remained motionless as long as the fan continued to operate. Squares were marked off on the screen to facilitate counting.

THE EXPERIMENT OF 1925

Eight relatively high producing cows, divided into 4 similar groups, were placed in 4 screened stalls, the two cows of each group being housed together. All groups were fed and cared for in the same manner, being milked twice daily and furnished, in accordance with their production, the same ration that they had been receiving prior to the experiment. Such data as amount and kind of food eaten, amount of water drunk, milk and fat produced daily, and body weight of the cows were kept, and in addition, the temperature and relative humidity in the stalls recorded.

During the first 10 days (June 5–14) all cows were kept free from flies. For the next 30 days flies were liberated daily in all of the stalls except that of group A, the controls. During the period, group B was exposed to a total of 73,000 horn flies; group C to 71,000 stable flies and group D to 140,000 house flies. Then followed a month in which all the cows were sprayed. As before, all groups except A were exposed to flies; group B to 19,600 horn flies and group C to 23,250 stable flies. In the case of group D, however, stable flies were substituted for house flies, 26,800 of the latter being added during the last month.

The sprays used were (1) an odorless, non-toxic, white petroleum oil of western origin, having a specific gravity of .8762, a flash point of 310 and

TABLE 1

Losses in milk production resulting from heavy infestations of flies

GROUP	TREATMENT	AVERAGE MONTHLY MILK PRODUCTION		LOSSES ATTRIBUTABLE TO FLIES	
		Expected lbs.	Actual lbs.	Lbs.	Per cent
A	No flies	.....	954	.....	.....
B	73,000 horn flies	677	667	10	1.4
C	71,000 stable flies	1055	957	98	9.3
D	140,000 house flies	890	860	30	3.3

a Saybolt viscosity of 105; and (2) a combination of 2 parts of the former and one part of an oil used for household spray containing an extract of pyrethrum in distillate. Though both were on the market under specific names, in this report they will be referred to as the white oil and yellow oil, respectively. The cows in groups A and B were sprayed with the yellow oil, while the white oil was used on groups C and D. A pressure tank gun was used, about 400 cc. being applied daily to each cow.

THE EFFECT OF FLIES ON UNSPRAYED COWS

In order to evaluate properly the effect of flies on milk production, the normal expectancy of the different groups was figured as follows: the rate of decline of 10 cows in the college herd similar to the experimental cows in stage of lactation and that of group A was determined for the month. Both were identical, falling off at the rate of 8.3 per cent. Using as a starting point the production of each cow during the first 10 days, when all flies were excluded from the stalls, and applying the above rate of decline, the expected production for each group was determined. Contrary to expectations, horn flies caused the slight loss of 1.4 per cent in milk production—negligible from a commercial standpoint, but a true reduction nevertheless, since Student's odds of 1–49 show that the results obtained were not due to chance but were consistent depreciations. The house flies caused a constant decline of 3.13 per cent, with a Student's odds of 1–347. This loss can be accounted for by annoyance only, since this species is not able to suck the blood or pierce the skin. As expected, the stable fly was the most serious pest. The reduction of 9.3 per cent, checked by Student's odds of 1–99,999, is large enough to be of economic importance.

THE COMBINED EFFECT OF SPRAY AND FLIES

The physical appearance of the animals after spraying was satisfactory. The oil collected very little dust, and the coats seemed sleek and soft. There was, however, a distinct falling off in milk production. Because group A, now being sprayed with yellow oil, could no longer serve as a control, the expected production of each group was arrived at by using the rate of decline for that month exhibited by the 10 cows in the college herd previously used for this purpose.

Table 2 summarizes the results. The animals sprayed with the yellow oil (white oil and pyrethrum) apparently suffered less than those sprayed with the straight white oil. Group A failed to make their expectancy by 4.3 per cent. Group C, which had suffered a loss of 9.3 per cent as the result of flies alone, now showed a decrease of 12.4 per cent. This increased loss is similar to the loss of 4.3 per cent exhibited by group A, which can be chargeable only to spray injury, as no flies were present.

TABLE 2

Losses in production resulting from the use of petroleum sprays during a heavy infestation of flies

GROUP	TREATMENT	AVERAGE MONTHLY MILK PRODUCTION		LOSS IN MILK PRODUCTION	
		Expected lbs.	Actual lbs.	Lbs.	Per cent
A	Yellow oil—no flies	942	900	42	4.3
C	Yellow oil—23,250 stable flies	986	862	124	12.4
D	White oil—26,900 stable flies	887	692	185	21.0
B	White oil—19,600 horn flies	654	566	98	13.1

With the straight white oil the results were more striking. The cows infested with horn flies, group B, which had suffered a reduction of 1.4 per cent with flies alone, now registered a loss of 13.1 per cent. Group D, now with stable flies, suffered a 21 per cent loss contrasted with the 9.3 per cent caused by stable flies alone.

EFFECT OF SPRAY ON THE FLIES

The white oil had very little effect on any of the flies. Horn flies caught in the vortex of the spray were killed apparently by mechanical action. Stable flies were slightly more susceptible than house flies in the case of a "direct hit." Thirty-six out of forty house flies placed in the center of a target that received (at the point where the flies were held) .05 grams of oil per square inch lived longer than controls that were not sprayed. Stable flies were invariably killed by this treatment, and when forcing their way through the oily hair of a sprayed cow often retreated and attempted to clean themselves. House flies, however, were not visibly affected by the presence of the oil on the cows.

The yellow spray had a definite toxic effect noticeable for several hours. The pyrethrum-oil portion of the spray was readily volatile, all effects, if used alone, disappearing in approximately forty minutes. When combined with the white oil, it remained effective for three or four hours, gradually losing its repellent properties until it was innocuous at the end of about 7 hours. Flies not repelled were paralyzed soon after alighting on the freshly sprayed animals. About half of these soon died; the others gradually recovered. Those ravenously hungry when liberated in the stalls attacked the animals in spite of the spray, and if they persisted long enough, were killed; but those not so hungry waited on the sides of the stall until the repellent action diminished.

The loss in milk production attributable to flies was as follows: horn flies, 1.4 per cent; house flies, 3.3 per cent; stable flies, 9.3 per cent. When

a bland non-toxic oil was applied in the presence of stable flies, the loss in production was 21.0 per cent; in the presence of horn flies it was 13.1 per cent. When pyrethrum, extracted in a light oil, was added to the above spray and applied in the absence of flies, the resulting loss was 4.3 per cent; when stable flies were present it was 12.4 per cent.

THE 1926 EXPERIMENT

A diligent search of the literature failed to disclose any research designed to show the effect of fly sprays on milk production. Our findings—that sprays applied in the absence of flies caused a marked reduction in milk, greater even than that resulting from a heavy infestation of stable flies—if substantiated, would be valuable information for the dairyman and spray manufacturer. Because of these facts, the work during the summer of 1926 was intended to check our previous findings on this point and to discover if possible the reasons why a loss in milk production should result from the use of fly spray.

Essentially the same procedure was followed, the principal deviation being in the type of sprays used. It had been suggested that the physical characteristics of the oil might influence its effect on the cow. In order to determine this, the white oil which had a specific gravity of .8762, flash point 310 and Saybolt 105 was replaced in this trial with a colorless, bland, eastern oil whose specific gravity was .8363, flash point 340, and viscosity 68 Saybolt.

For the combination of white oil and pyrethrum there was substituted a non-petroleum spray made by emulsifying with sodium hydroxide, equal parts of pine tar and creosote. When used, this stock solution was diluted with 97 parts of water. Applied at the previous rate of approximately 400 cc. per animal, the petroleum product had an average repellent efficiency for 24 hours of 83 per cent, determined from the fly counts of sprayed and unsprayed animals. This figure for the pine tar-creosote was 78 per cent.

The results were essentially in agreement with those of the 1925 experiment, in that there was a definite loss attributable to the effect of fly sprays. The pine tar-creosote engendered a decline of 12.5 per cent in milk production. The petroleum spray caused a dropping off of 22.8 per cent, as contrasted with a 11.7 per cent loss for the white oil in the previous trial. An extremely hot spell in 1926 (in the light of later work) undoubtedly accounted for the increased detrimental effect of this spray.

During periods of high temperature, the clinical picture of the oiled cows was one of extreme distress, while the untreated animals were affected but little. To a lesser extent this was true of the group sprayed with pine tar-creosote. As soon as this condition was noticed, respiration counts and body temperature readings were taken at 2 hour intervals throughout the

day. Table 3 shows the extent to which the animals sprayed with petroleum suffered when subjected to a high environmental temperature.

TABLE 3

The effect of hot weather on the body temperature and respiration rate of high producing cows when sprayed and unsprayed

DATE, 1926	MAXIMUM DAILY TEMPERATURE DEG. F.	MAXIMUM BODY TEMPERATURE		MAXIMUM RESPIRATION RATE	
		Group A unsprayed deg. F.	Group B sprayed deg. F.	Group A unsprayed per min.	Group B sprayed per min.
June 24	92	102.2	104.2	70	125
" 25	101	103.5	106.5	85	141
" 26	98	102.9	106.0	90	135
" 27	102	103.2	106.5	85	145
" 28	100	103.5	106.1	100	140
" 29	90	103.0	104.5	95	130
" 30	82	102.6	102.6	71	112
July 1	92	103.0	105.1	77	125
" 2	96	102.8	106.0	88	137
" 3	100	102.8	103.6*	90	125*
Average	95.3	102.9	105.1	85	130

* Sprayed cows washed at 10 A.M.

While the normal body temperature of the cow lies usually between 101 and 102° F., it may at times reach 103° F. In spite of the stupendous effort being made by the sprayed animals to maintain a normal body temperature, as evidenced by the extremely rapid respiration of 130 breaths per minute, their average body temperature was of fever proportions, being 105.1° F. The unsprayed cows, on the other hand, were not greatly affected, as shown by an average of 102.9° F. for body temperature and a respiration rate of 85 per minute. That the fly spray was responsible for this fever and rapid breathing is further indicated by the fact that in the case of the untreated cows, there was little if any relation between environmental temperature and the respiration rate and body temperature, the correlation coefficient for the latter being .6841 $\pm$ .019. In the case of the oiled animals, however, these values rise and fall with the maximum daily temperature, an almost perfect correlation of .95679 $\pm$ .00387 being found to exist between the environmental and body temperatures.

Again the animals used were relatively high producers. Those in group A, the controls, averaged 41 pounds of milk and 1.5 pounds of butter fat daily, and those in group B, the treated animals, 36 pounds of milk and 1.8 pounds of butter fat.

On the advice of the University veterinarians, spraying was discontinued and the cows washed repeatedly in order to avoid permanent injury. Immediate relief followed each washing but the distressed condition was again

evident in a few hours, about a week being required before normal body temperature and respiration returned permanently.

The clinical picture led us to believe that productive ability might be a factor in the complex. To determine this, a group of dry cows were sprayed heavily with petroleum oil and even though the same high environmental temperatures prevailed, body temperatures and respiration rates were not elevated above the normal.

THE 1931 EXPERIMENT

In the light of modern fly spray practice, our results of the previous two years were subjected to the criticism that we had applied too much spray. Our standard of 25 cc. per 100 pounds of live weight, from 250 to 400 cc. per cow, daily, was an arbitrary one, arrived at by increasing the dosage until 80 per cent of the flies were repelled for 24 hours. Most commercial fly sprays have a petroleum base to which is added pyrethrum or pine oil or both. The repellent, and to some extent, the toxic action of the pyrethrum and pine oil, increases the efficiency of the spray, thus decreasing the amount necessary to apply. In many cases commercial household spray is added to a heavier oil to avoid the burning or irritating action on the skin that follows when it is used undiluted. Many claims have been made for the relative merits of unsaturates *versus* completely saturated oils; heavy *versus* light oils, and wide blends *versus* straight cuts or close blends. The 1931 trials were begun early in May with an attempt to choose the most effective insecticide for further trials of their effect on the animals. Later the two most promising of these were used at the rate of 40 cc. per day (commercial dairy practice) on high producing cows under controlled conditions of temperature and humidity.

In table 4 are given the principal characteristics of the sprays used in tests of repellent efficiency.

TABLE 4

Principal characteristics of sprays tested

NAME	BOILING RANGE	VISCOSITY	UNSULPHONATED RESIDUE	TOXICS
	Deg. F.	Saybolt at 100 deg. F.		Per gal.
Straight cut	550–660	54	93	¾ lb. pyrethrum
Close blend	379–690	40	86	½ lb. pyrethrum + 3% pine oil
Medium blend	320–640	40	89	½ lb. pyrethrum + 3% pine oil
Crude blend	316–757	36	63	½ lb. pyrethrum + 4% pine oil

Four groups of 4 cows each were chosen so as to be as nearly alike as possible in size and color. The trial covered 3 periods of 10 days each. In periods 1 and 2, all cows were kept in the barn. During the first period 20 cc. of spray was applied daily to each cow except those in group A. In period 2 the daily dosage was raised to 80 cc. Throughout period 4, the animals were confined to an open corral, those treated receiving 40 cc. daily. For this part of the trial another lot, group E, was added for treatment with the close blend.

Group A remained untreated, group B received straight cut, group C the medium blend, and group D the crude blend. The number of flies on each animal was counted at hourly intervals during the period of daylight. These counts furnish the basis for computing the percentages of efficiency given in table 5.

TABLE 5

*Percentage repellent efficiency of sprays applied under varying conditions**

ANIMALS USED	SPRAY USED	PERCENTAGE OF EFFICIENCY				
		Period 1		Period 2	Period 3	
		First hour	24th hour	Average for first 5 hours	Average first 5 hours	Average first 8 hours
Group B	Straight cut	96	0	87	80	59
Group C	Medium blend	98	33	94	74	54
Group D	Crude blend	92	0	94	73	53
Group E	Close blend	.....	.....	.....	85	70

* During period 1 cows in barn, dosage 20 cc; period 2 cows in barn, dosage 40 cc; period 3 cows in corral, dosage 40 cc.

In period 1, the three oils used repelled flies with about the same effectiveness for the first hour, all being above 90 per cent. At the end of 24 hours, however, the straight cut and crude blend had lost all repellent power, while the medium blend still exhibited a 33 per cent efficiency. In the second period, the medium and crude blends, both containing pine tar, showed a higher average efficiency for 5 hours than did the straight cut, which contained only pyrethrum. However, in the third period, the latter mixture was about as effective for the same length of time when the dosage had been cut in half. The repellent properties of the other two were not so persistent when the smaller dosage was used. Because of the greater efficiency for a longer period of time, the straight cut and medium blends were chosen in our subsequent trial to determine the effect on the cow when lightly applied.

Burning of the skin, as indicated by redness and sloughing, followed the use of oils having a viscosity lower than 40 seconds, irrespective of the unsulfonated residue. White oils with unsulfonated residues of 90 per cent were dangerous when used with oils of a viscosity greater than 65 seconds.

The comfort of the cow, as affected by temperature, humidity, and air movement has an important bearing upon the amount and quality of milk she is able to produce. In our previous trials, 1925 and 1926, it had been difficult to evaluate the effect of these uncontrolled environmental variables upon our results. In the meantime the installation of a psychrometric room, large enough for the stabling of 2 cows, where the air movement could be kept constant and the temperature and humidity regulated and maintained at will over a wide range and for long periods of time made possible the control of these environmental factors.

Two high producing Jersey cows in the same period of lactation were placed in this room, and after a period of 10 days, in which they were permitted to become accustomed to their new surroundings, their upper critical temperature or "pyrexial point" was determined by gradually increasing the room temperature and, at the same time, maintaining a constant relative humidity and air movement.

It was found that at 80° F. the animals remained normal, but at 85° F. they were no longer able to control body temperature, which rose to fever proportions. The application of 40 cc. of fly spray per animal daily, even though the environmental temperature was but 80° F., resulted in a marked rise in body temperature. The details are shown graphically in Figure 1.

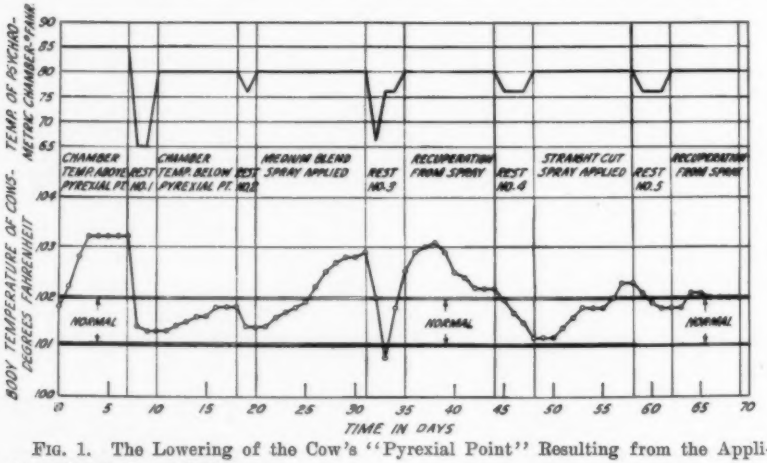

FIG. 1. The Lowering of the Cow's "Pyrexial Point" Resulting from the Application of Petroleum Fly Sprays.

The upper heavy black line shows the chamber temperature, while the curve in the lower half of the chart is that of the average body temperature of the two cows. During the first 7 days, when the room was held at 85° F., the body temperature quickly rose to 103.2° F. After a short rest period of 3 days at 65° F., the chamber temperature was maintained at 80° F. for

a week, during which time the body temperature remained normal. Then followed a short rest period at 75° F., after which 40 cc. of medium blend spray was applied daily for 10 days. The average body temperature of the animals gradually mounted, finally reaching almost 103° F. The cows were now washed with warm water and soap to remove the spray, and the environmental temperature was lowered. Though the effect of the washing was immediate, upon the resumption of a room temperature of 80° F., the body temperature quickly mounted again to 103° F., gradually returning toward the normal. This, it should be remembered, was during a period without spray, when the body temperature should have been between 101° F., and 102° F. The straight cut spray next applied in the same dosage was not so marked in its effect, and recovery was more rapid following washing during rest period 5.

THE 1933 EXPERIMENT

These trials had a threefold purpose. They were designed (1) to check our previous conclusion that the use of light applications of petroleum fly sprays impair the efficiency of the cow's thermo-regulatory apparatus; (2) to shed some light on the fundamental reasons for this impairment; and (3) if possible, to develop an effective repellent that could be used with safety.

Two high producing Jersey cows were placed in the psychometric chamber. Their body temperatures, and the pH and rennet coagulation time of their milks were determined for periods of 10 days at environmental temperatures of 75, 80, and 85° F. The chamber temperature was then lowered to 80° F. for 10 days to allow the animals to recuperate. During the last 10 days, 20 cc. of commercial fly spray was administered to each cow daily, the room temperature being held at 80° F. Uniform conditions of feeding, management, relative humidity, and air movement were maintained throughout the trial. The results are given in table 6.

TABLE 6

The effect of fly spray on the pyrexial temperature of cows, and on the rennet coagulation —time and pH of their milk—ten day average for 2 cows

LENGTH OF TRIAL	TREATMENT	ROOM TEMPERATURE	BODY TEMPERATURE	RENNET COAGULATION TIME OF MILK		pH OF MILK
days		*deg. F.*	*deg. F.*	*min.*	*sec.*	
10	Unsprayed	75	101.5	4	01	6.57
10	Unsprayed	80	101.5	3	45	6.56
10	Unsprayed	85	103.1	4	46	6.75
10	Unsprayed	80	101.6	3	52	6.55
10	20 cc. commercial fly spray daily	80	102.8	5	03	6.60

Unpublished data, collected at this station, show quite clearly that when the environmental temperature is maintained at or above 85° F. for more than 24 hours, heavily producing Jersey cows are no longer able to maintain a normal body temperature and that the time required to coagulate with rennet the milk produced under these conditions, is lengthened, and its pH increased. The environmental temperature at which this feverish condition is initiated, we have called the "pyrexial point."

In table 6, it will be noted that the body temperature remained normal and there was very little variation in the values for the milk at 70° F. and 80° F. At 85° F., however, body temperature rose to 103.1° F., the time required to coagulate the milk increased about 1 minute, and its pH increased to 6.75. On resumption of the 80° F. condition, the former values returned. The spraying, however, had an effect on the comfort of the cows equivalent to a 5 degree rise in air temperature, or in other words, spraying the animals had lowered their "pyrexial point" 5 degrees.

Circles, 35.7 square centimeters in area, were now marked off on the rumps and loins of each Jersey. Then, by means of inverted Petri dishes, in the bottoms of which were fastened filter papers impregnated with calcium chloride, the moisture transpired by a given area during an hour was determined. At 84° F. these areas gave off on an average 333 milligrams of water per hour. The right rump area on each cow was then treated daily with the amount of commercial fly spray that it would have received in a general light spraying (40 cc.) of the entire cow. The surroundings were protected so that the oil reached only the area within the circle. During the first 24 hours the water given off by the untreated circles was but 32 milligrams more than that from the treated. In the succeeding days, however, the sprayed areas transpired only 180 milligrams per hour, as contrasted with an expectancy of 333, an hourly loss of 153 milligrams due to oiling.

From the psychrometric room, the cows were transferred directly to the respiration chamber where, without any change in ration, the basal metabolism of each was measured. The average total daily dissipation of heat was found to be 17,920 large calories per animal. When the data from the circular areas were transposed to total surface figures, the cow's hourly loss of moisture at 84° F. and 60 per cent relative humidity was found to be 413 grams, about 1 pound, whereas for the lightly sprayed animal it amounted to only 223 grams. These figures translated into terms of cooling power (heat necessary to vaporize these amounts of water at 84° F. and 60 per cent relative humidity) show that the water passing through the skin is responsible for the dissipation of 5,698 large calories daily, or 31.8 per cent of the total heat lost in the case of the unsprayed animal. In the sprayed skin this cooling power is reduced to the absorption of 3,075 large

calories and thus becomes only 17 per cent of the total heat lost. This represents a loss of 46 per cent in the cooling power.

The source of the moisture present on the skin of the cow has caused considerable controversy. Whitehouse, Hancock and Haldane (14) have shown that water passing through the human skin by osmosis or diffusion increases directly as the temperature increases, until sweating commences, when the saturated surface stops the passage of the so-called osmotic water.

They have suggested that the passage of osmotic water through the skin is directly connected with the abundance of capillary blood in the peripheral system. To see whether the oil had a definite effect on the capillaries, we measured the diameter of a given capillary in a rabbit's ear with a binocular microscope and an eye-piece micrometer. Repeated readings at given temperatures gave the following constant results:

ROOM TEMPERATURE	50° F.	70° F.	85° F.	90° F.
Normal	.84 mm.	1.05 mm.	1.05 mm.	1.89 mm.
After spraying	1.57	1.57	2.10	2.10

A light spraying with a hand atomizer produced, at the end of 24 hours, the results indicated above. The capillaries showed a greater dilation at the higher temperatures and failed to contract to normal when the temperature was reduced to 50° F. Though no typical inflammation, as indicated by the flushing of the tissue, was observed in these trials when the oil was sprayed, we are inclined to attribute to an incipient inflammation the failure of the capillaries to maintain their normal powers of dilation and contraction. Other rabbits whose ears were swabbed with the same fly spray showed the same general reaction, which, however, progressed further, resulting in highly flushed tissue, edema, and a fuzzy outline of the arterioles, marking a typical mechanical inflammation.

The cow is thought to be inadequately supplied with sweat glands. Although the actual source of moisture was not a pertinent point in our investigation, we carefully washed a measured area on the sides of two cows and subjected the animals for two hours to temperatures of 85° F. and 115° F. Between these exposures, the areas were carefully washed with distilled water, which was then analysed for sodium chloride as an indication of sweat gland activity. The results, 47 milligrams at 85° F. and 45 milligrams at 115° F. per square meter washed, showed negligible differences. At no time were amounts found that might not have been attributed to extraneous sources. If sweat were an important factor in the moisture production, then proportionally greater increases in chlorides should have been obtained at the higher temperatures. Consequently, it seems safe to attribute the appreciable amount of moisture transpired from the surface of the cow's skin almost entirely, if not wholly, to osmotic water.

Believing that the petroleum oil carrier of the toxics and repellents was the main injurious factor in the spray, we attempted to combine pyrethrum extracts and pine oil in water emulsions. Although these could be applied without injury to the animals, their efficiency against flies was so low that they were modified, the pyrethrum extract and pine oil being combined with a small amount of petroleum oil and then emulsified with water to make a stock solution, capable of further dilution with water at the time of application. The formulas for these emulsions were so arranged that they contained the same amount of pyrethrum and pine oil as had previously been used in sprays employing petroleum oil carriers (1.2 cc. of a 19 to 1 pyrethrum extract a cow, and 3 per cent pine oil in 40 cc.). We used several different sprays containing the same active ingredients but various emulsifying agents. These were applied immediately after mixing and again when they were six months old. As expected, those containing an alkaline emulsifier, such as potassium abietate, showed a slight deterioration in efficiency at the end of six months' storage, while those utilizing so-called neutral emulsifiers, like diglycol oleate and triethanolamine oleate, remained just as efficient after storage as when freshly mixed. As shown by the net results of the trials, these emulsions were 80 per cent effective over an 8-hour period. In fly-repelling efficiency, they equal or excel the better brands of commercial fly sprays. The best emulsions used have the following formulas:

FORMULA 1

Petroleum oil	84 cc.
Unsulphonated residue	90
Viscosity	97
Pyrethrum extract (19–1)	48 cc.
Pine oil, steam distilled	48 cc.
Specific Gravity	.9377
Boiling point	194–217
Color	1 NPA
Triethanolamine oleate	16 gms.
Water	100 cc.

Dilute one part of this stock emulsion with four and one-third parts of water.

FORMULA 2

Petroleum oil (as above)	50 cc.
Pine oil (as above)	50 cc.
Pyrethrum extract (as above)	50 cc.
Diglycol oleate	28.9 cc.

Dilute slowly with eight parts of water, agitating vigorously.

Applications of these emulsions properly diluted with water caused no rise in body temperature but did produce a loss in the transpired water. Animals treated with the emulsion type spray made with diglycol oleate transpired only enough water to dissipate 24.6 per cent of the total heat, as contrasted with 31.8 per cent for normal unsprayed cows. Apparently

increased respiration, sweating in limited, localized areas, and body radiation can compensate for this loss at 84 degrees; but at higher environmental temperatures some rise in body temperature would probably be experienced.

DISCUSSION

The general conclusion to be drawn from these trials is that the application of fly spray augments the relatively small losses attributable to fly annoyance. This conclusion is distinctly at variance with the popular belief that flies exact a heavy toll, which is minimized by spraying.

It is not difficult to see how the dairyman has been led to this belief. The comfortable surrounding and excellent feed conditions that exist naturally in the spring and early summer make this season ideal for milk production. The appearance of flies in greatest numbers is coincident with the onset of summer heat and the drying up of the pastures. It is not surprising then that the dairyman should attribute to flies the marked decline in milk flow caused by hot weather and under-nutrition. Moreover, his faith in the efficacy of fly repellents has been fostered by the sales promotion activities of spray manufacturers and by the advice of certain experiment station and extension workers.

In our studies, the exposure of cows to stable fly infestations many times more severe than would be found under ordinary field conditions (the screened stalls were literally swarming with flies) resulted in less than a ten per cent loss in production. Invariably, however, this loss was about doubled when oil sprays were used to protect the cows, especially in hot weather.

When the average daily environmental temperature remains at 80 or 85 degrees F., depending upon the breed, for more than 24 hours, the heat regulating mechanism ceases to function adequately and the cow exhibits symptoms of distress. At this critical temperature, which we have called the "pyrexial point," her body temperature rises, her milk flow declines, and the physico-chemical characteristics of her milk are altered.

Some critics of our work have failed to distinguish between true burning with its attendant visible lesions, which can be produced by careless application with practically any commercial petroleum fly spray and the less easily observed but more frequently produced condition wherein the body temperature is raised without evident skin lesions following normal spraying.

Shortly after our publication of 1932, (12) Melvin (1932) (6) and later Wilson, Pearson, and Cannon (1933) (8) published the results of numerous experiments covering much the same type of data, in which they confirmed many of our findings; but in reading the temperature of the cows under trial overlooked the fact (already pointed out by us) that above a given "pyrexial point," differing for the breeds, a normal cow, even though unsprayed, cannot control her body temperature. We have shown, quite

clearly, we believe, that oil sprays reduce the amount of osmotic water passing through the skin, thus impairing the efficiency of the cow's thermoregulatory apparatus, in effect, lowering her "pyrexial point," and in consequence, the environmental temperature at which she is able to maintain a condition of comfort.

In studying the results of our first trials (1925), we were inclined to attribute to the mechanical action of the blanket of oil, this increase in body temperature, since we were using at that time, a bland oil, uncomplicated by toxics, having a purity from unsaturates comparable to that of medicinal petroleum. Subsequent trials have always demonstrated two characteristics that refute this idea. In the first place, at least 24 hours must elapse before the feverish condition is noticed. And also, whenever animals exhibiting a body temperature above normal are thoroughly washed with soap and water to remove the spray, their temperatures quickly return to normal only to rise to fever proportions again as soon as the effect of the evaporating water has disappeared. In the absence of further spraying, about a week is required for the animal permanently to resume a normal body temperature.

These facts seem to preclude the possibility of purely mechanical surface action and point strongly to a chemical combination with the tissues. In addition, oils of low unsulfonated residues are certain to produce these unfavorable reactions in a shorter time and with more intensity, a fact which substantiates the theory that the problem is chemical in nature. The striking similarity between the effects of petroleum oils on animal and on plant tissues is perhaps worthy of further consideration.

The kind of spray, the amount applied, the productive capacity of the cows, and the environmental temperature are all important factors in determining the deleterious effect of the spray. This is most marked when the high producing cow is treated with a generous application of a petroleum base spray in hot weather.

In view of the small losses that may be rightfully charged to flies, it is difficult to see how the use of sprays can be justified on economic grounds alone.

CONCLUSIONS

(1) The loss in milk production caused by flies is often overestimated. When high producing cows were exposed to extremely heavy infestations, the loss occasioned by house flies and horn flies was negligible; that caused by stable flies was slightly less than 10 per cent.

(2) Fly sprays of petroleum oils carrying pyrethrum or pine oil or both were tested. All had the same repellent efficiency for the first hour but differed at subsequent intervals. Pine oil increased their efficiency in proportion to the amount added.

(3) Burning of the skin followed the use of oils having a viscosity lower than 40 seconds, irrespective of the unsulfonated residues; while oils with unsulfonated residues below 90 per cent were dangerous, when used in oils of higher viscosity than 65 seconds.

(4) When petroleum sprays were used to repel the stable flies, the loss in milk yield was increased to 22 per cent.

(5) The extreme effect was evident when high producing cows were sprayed during hot weather. Not only was production diminished but the body temperature and respiration rate were elevated. Dry cows exhibited no increase in temperature or breathing rate when sprayed.

(6) The application of oil produces on the skin a definite physiological effect, impairing its ability to aid in maintaining body temperature.

(7) The hourly loss of water through the skin of the unsprayed cow at 84° F. and 60 per cent relative humidity, was 413 grams, while for the sprayed animal this figure was 223 grams. This represents a loss of 46 per cent in cooling, due to the loss in evaporation of water from the skin.

(8) When 40 cc. of commercial spray was applied at an environmental temperature of 80° F., the upper critical temperature or "pyrexial point" of the cow was lowered approximately 5° F.

(9) A water emulsion of pyrethrum and pine oil combined with a small amount of petroleum was as efficient in repelling flies as the petroleum sprays and was less detrimental to the cows.

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SOFT CURD CHARACTER INDUCED IN MILK BY INTENSE SONIC VIBRATION

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The investigations reported by Hill (4, 5), Espe and Dye (3), Elias (2), Weisberg, Johnson and McCollum (7) and others have aroused widespread interest in the use of soft curded milk in the feeding of infants, convalescent gastro-intestinal patients, and even of normal children and adults. It has been demonstrated that curd consistency is an index of the time required for gastric digestion of a given milk. Furthermore, Hill has shown that the average curd texture of milk varies greatly from breed to breed of cattle; that the curd may vary from 15 to 200 grams tension (Hill test) in different individuals of the same herd; and that a variety of factors may cause variations in the curd texture of milk from a single individual. At present many attempts are being made to modify milks of average or hard curd texture by suitable additions, subtractions, or mechanical means. If such modification can be accomplished the product should have real nutritional and clinical value as a special grade of milk, if indeed it has not a practical value wherever fluid milk without further modification is destined for human consumption.

Available and suggested methods for lowering the curd tension of milk are for the most part open to criticism on the ground of adulteration, particularly where some foreign substance such as citrate or metaphosphate is added or where the Ca balance is disturbed by removal through adsorptive or other processes. Curd softening by pressure homogenization is practicable as shown by Theophilus, Hansen and Spencer (6) but seems never to have been employed extensively. Failure to use the method seems to have resulted from milk plant regulations prohibiting the use of homogenizers and from economic considerations.

While investigating the action of intense sonic vibration on the bacterial flora of milk (partially reported elsewhere by Chambers and Gaines (1)), it was found that the curd tension of the vibrated milk was effectively lowered. It is the purpose of this paper to report the results of an investigation of this phenomenon together with certain theoretical and practical implications.

APPARATUS

Two general types of intense sonic energy sources were employed:

1. Electromagnetic oscillators available were similar to those used in submarine communication and echo depth sounding consisting essentially of a

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heavy, loaded, steel membrane actuated by alternation in an electromagnetic circuit (See Figure 1). Three oscillators of this type were available with resonant frequencies of approximately 1200, 2160, and 3000 cycles per second respectively. Power was supplied from appropriate motor driven generators at one half the oscillator frequency since the diaphragms were non-polarized. Input of electrical energy in each case was from 400 to 600 watts depending somewhat on the loading conditions. Actual output of acoustic energy at 1200 cycles was approximately 175 watts while the electrical efficiency of the other oscillators was considerably lower. In fact the acoustic output of the 3000 cycle apparatus was so low that no satisfactory tests could be made at that frequency.

2. Oscillators of the Fessenden type were also used, in which the vibrating membrane is fixed to a copper tube, the whole being polarized by an inciting current of about 2.75 amperes. Movement of the diaphragm depends on reversal of eddy currents in the copper sleeve induced by current oscillations in the activating coil. Consequently the frequency of vibration is equal to the frequency of the activating current and not twice that value as in the electromagnetic oscillators. Two oscillators of the Fessenden type were used, one with a resonant period of about 1090 cycles, the other with resonant periods at 360 and about 610 cycles. Power input was variable

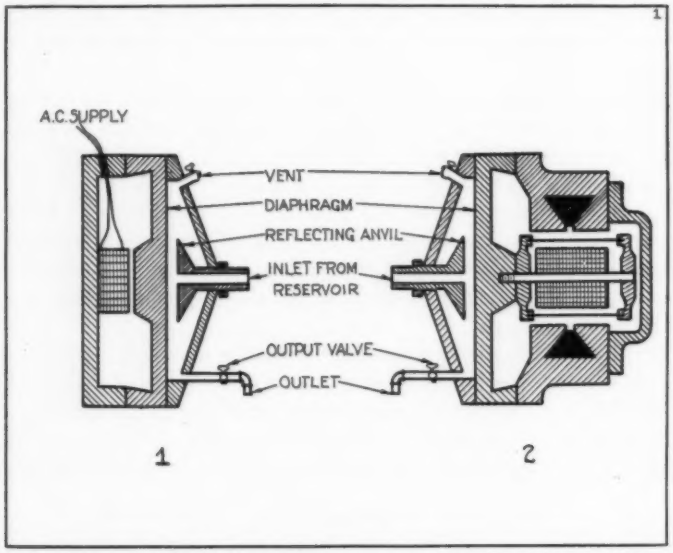

FIG. 1. Diagrammatic sketch showing essential construction features of electromagnetic (1) and Fessenden (2) type oscillators together with accessory apparatus used in applying sonic vibrations to milk. Drawings are not to scale. Oscillators of type 1 were 13⅜" in diameter while those of type 2 were about 24" in diameter.

up to 2200 watts. The electrical efficiency was about 45 per cent except at the 610 cycle resonance point where the power ratio was somewhat lower.

All the oscillators of both types were manufactured by the Submarine Signal Company of Boston, and, with the exception of the three thousand cycle unit, all are standard equipment in submarine communication and echo sounding work.

Accessory equipment used in securing a uniform application of energy to every portion of milk passed over the oscillator was similar in the two cases. (See Figure 1.) It consisted of a heavy bell metal cover, tin dipped, bolted to the margins of the steel diaphragm. Two marginal openings were provided, one for the ingress or egress of milk and one to enable elimination of an air pocket from the chamber formed between cover and diaphragm. In addition a central opening was provided as an outlet or inlet for milk. This opening passed centrally through a stainless steel "anvil" or reflecting plate capable of micrometer adjustment in such a way that the layer of milk between anvil and diaphragm could be reduced to any desired value up to one half inch in steps of .001 inch. The reflector was three inches in diameter in the electromagnetic oscillator and six to seven inches in the Fessenden type, thus covering most of the strongly active area of the diaphragms. In most experiments the anvil surface, and in a few cases the diaphragm surface as well, were machine scored to increase the turbulence of milk flow over the active area.

Accessory apparatus was also provided for forcing of flow by the application of pressure. This, however, was little used since gravity feed was found to provide as great a flow as could be handled conveniently except where the anvil-diaphragm clearance was less than .040 inch.

EXPERIMENTAL

Most of the milk used in the experiments was obtained from the Deerfoot Farms Dairies of Southboro, Massachusetts. The curd tension of the original supply from this source was regulated within ten gram limits through analysis of the product of each individual in a herd of Jerseys and Guernseys kept at the Farm. With knowledge of the relative curd hardness of milk from individual animals it was possible to obtain hard, medium or soft curded samples at will. In addition, bulk milk, both raw and pasteurized was supplied by the same dairy from mixed herds, presumably largely of Holstein origin.

To insure a representative study samples of milk were also secured from five other sources in the Boston milkshed area. No differences in the behavior of the various milks were detected which could have been accounted for by difference of source.

The curd tensions of the approximately 500 samples taken over a period of eleven months varied between 14 and 140 grams. An interesting con-

firmation of Hill's observation that harder curded milk is produced during cold than during warm weather resulted from this series of determinations. During July and August the average tension of all mixed samples was about 32 grams while the onset of cool weather brought a gradual rise until the average figure for November and December was 63 grams. Daily fluctuations in the curd tension of mixed milks paralleled roughly the fluctuations in average daily temperature.

The Hill technique (5) was used in the determination of the curd tension in all cases. Great care was exercised in maintaining the water bath temperature constant within ± 0.2 of a degree as it was found that greater variation resulted in large errors. As insurance against possible faulty technique a number of samples were sent to the National Dairy Laboratories in Baltimore. The measurements made by Doctor Weisberg checked our own within five grams. Greater accuracy could be of little value in this study.

While variations were introduced in individual experiments the general method of handling the milk before, during, and after exposure to vibration was as follows:

1. Milk was warmed or cooled to the desired temperature in a water bath.
2. The oscillator and accessory equipment including all surfaces with which the milk might come in contact were thoroughly cleansed and then warmed to the desired temperature by flowing hot water through the system.
3. After control samples were taken the milk was placed in the reservoir and the oscillator chamber allowed to fill. Usually any air pocket remaining in the chamber was excluded by opening the vent. (See Figure 1.)
4. Vibration was begun and the rate of flow of milk adjusted by regulation of the outlet valve.
5. Samples were taken only after sufficient time had elapsed to insure complete removal of milk originally introduced into the oscillator chamber.
6. The samples were placed in the water bath at 35° C. for immediate test, or were stored at 10° C. for delayed tests. A difference of 24 to 48 hours in elapsed time resulted in no significant change in the curd tension either of treated or untreated samples.
7. In most cases 100 cc. samples were stored at 10° C. in graduate cylinders for measurement of cream volume after 24 hours.
8. Microscopic examination of treated and untreated samples was made to determine relative average and maximum fat particle size and relative degree of pedesis.

EXPERIMENTAL RESULTS

Qualitatively the results of vibration of milk with the two types of oscillator were closely parallel. Consequently the task of summarizing the data of more than 600 experiments can be simplified by considering the extent of curd reduction with respect to energy input, volume, and temperature

for the entire group of oscillators at the same time, indicating those points at which significant divergences exist. No useful purpose would be served by including detailed protocols of all experiments. Instead significant averages over large groups of related experiments will be utilized together with indications of the extremes of individual measurements.

Extent of curd reduction in 3.5–4 per cent milk

Much of the experimentation was of an exploratory nature to determine the effect of all possible variations in method of handling on the degree of change in curd texture. Attention was given to variations in rate of flow through the oscillator, temperature of the milk during exposure, electrical energy output to the oscillator, acoustic energy output of the oscillator (where feasible), curd tension in the untreated milk samples, the degree of dispersion of the butter fat, and clearance between reflecting anvil and oscillator diaphragm. These will be taken up in order:

A. *Reduction in curd tension as a function of exposure time (rate of flow).*

All other variables remaining constant the degree of reduction in curd tension is a rather complex function of the velocity of milk flow through

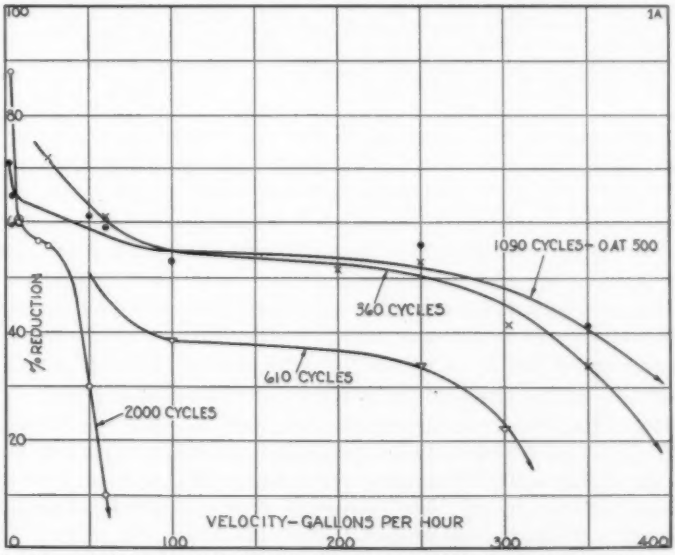

FIG. 2a. Variation in % R (=100 – Final tension/Original tension) with respect to rate of flow (velocity) through three different oscillators, one of which was operated at two frequency levels (360 and 610 cycles). All points represent averages derived from experiments on both hard and medium curd milk. All samples were preheated to 40° – 60° C. Power inputs were: 1800 watts at 1090 cycles, 1400 at 610 cycles, 1900 at 360 cycles, and 600 at 2000 cycles.

the oscillator. (See Figure 2.) In the larger Fessenden oscillator with essentially equivalent power inputs this peculiar relationship becomes apparent only at velocities greater than 100 gallons per hour. At less than 100 gallons per hour velocity is an exponential function of the percentage reduction in curd tension. From 100 to about 250 gallons per hour the relationship becomes linear with zero slope. At higher velocities the curve is such that no reduction in curd tension is produced when the flow exceeds 500 gallons per hour.

The actual values of % R (per cent reduction in curd tension) differ somewhat at the three frequency levels available with the Fessenden oscillators (cf. Figure 2A), *i.e.*, 360, 610, and 1050 cycles, but the shape of the curve remains sensibly constant. Variation in position with respect to the % R axis is explainable on the basis of relative electrical efficiency at the three frequency levels. The 360 cycle oscillator with an efficiency of 45–47 per cent at resonance delivers more acoustic energy than does either of the remaining units, power consumption being held at the same level in all three cases.

As indicated by the curve (Figure 2A) the average reduction in curd tension at power inputs of 1800 watts to 2200 watts varied as follows:

GALS./HOUR	% R AVERAGE	% R EXTREMES
25	73%	53% – 78%
100	52%	40% – 69%
250	53%	35% – 70%
350	34%	25% – 51%

These values cover experiments with a variety of clearances between anvil and diaphragm, various temperatures between the melting point of butter fat (35° C.) and 60° C., and include studies on both medium curd (30–60 grams) and hard curd (above 60 grams) milks. The effect of these variables on the net result is relatively unimportant as will be seen later, except for the difference in values for hard and soft curd milks. Figure 2B includes curves showing the average tension reductions for the two general groups when averaged separately. Medium curd milk at comparable rates of flow shows a smaller percentage reduction than does milk in the hard curd group. It is interesting to observe that this relative ease of reduction has been found to hold for curd tension changes produced with the standard pressure homogenizer.

From the extensive available data it is apparent then that the velocity at which maximum efficiency of curd reduction is attained at a given power input is approximately 250 gallons per hour where the 360 cycle oscillator is used. The same values have been found to hold true for the Fessenden oscillator operated at 1050–1125 cycles. The physical conditions

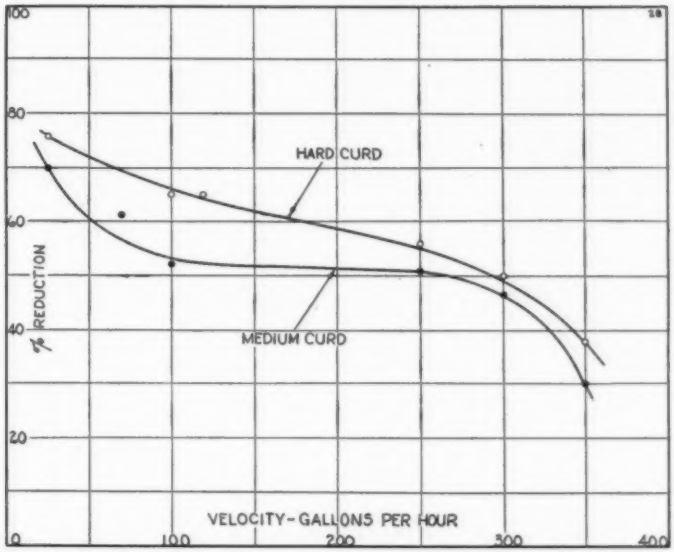

FIG. 2b. Variation in % R with respect to velocity in milks of the medium (30–60 gram) and hard (60 grams and up) curd groups. Treated at 360 cycles, 1900 watts, 50° – 60° C.

of treatment were identical with the exception of frequency and reductions in curd tension differed from those obtained at 360 cycles by only one or two per cent over the entire range of velocities.

Comparison is more difficult in so far as the 610 cycle oscillator is concerned since the possible power input at this frequency was limited to about 1400 watts. However, the general shape of the curve was quite similar to that obtained with the two preceding frequencies.

The significance of the plateau in the characteristic velocity curve for these three types of oscillators is not quite clear. However, it is probably produced by variations in the degree of turbulence in the oscillator chamber at different velocities of flow.

The relation between percentage reduction and velocity in the electromagnetic oscillators (1150 cycles, 2160 cycles, and 3000 cycles) are of the same general type as reported above, the only significant differences lying in the position of the plateau region relative to the velocity axis. Thus in both the 1150 and the 2000 cycle oscillators the portion of the curve with zero slope falls between 12 and 25 gallons per hour, while only negligible reductions in curd tension are obtained at 65 to 70 gallons per hour. It should be remembered however that the power input in these two cases was invariably less than 600 watts and further that the electrical efficiency of the two oscillators is only about half that of the large 360 cycle Fessenden.

B. *Extent of reduction as related to temperature.*

With all types of oscillators reduction in curd tension of ordinary whole milk was accomplished only when the milk was heated to a temperature higher than the melting point of butter fat, that is, above 35° C. No reduction of any measureable extent was ever accomplished in milk treated below 18° C. Figure 3 is a typical curve relating the percentage reduction

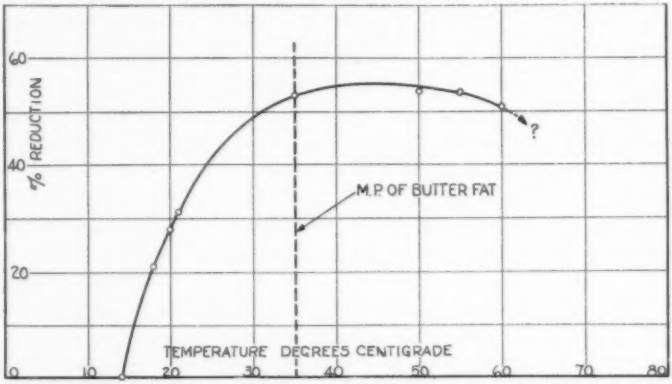

FIG. 3. Variation in % R with respect to temperature of the milk during vibration. Treated at 250 gallons per hour, 1900 watts, 360 cycles.

in curd tension to the temperature of treatment. It will be noted that an optimum temperature was reached at 35° and that increase up to 55° resulted in no further increase in efficiency of the process. There seems to be a tendency toward reduced effectiveness when the treatment temperature is greater than 55°.

In general it can be said that there is no curd tension reduction below 18°, very little between 18° and the melting point of butter fat, while a maximum reduction is obtained at temperatures above the melting point.

C. *Extent of reduction as related to power input.*

The most extensive studies of the relation between degree of change in curd texture and the amount of power applied have been made in the case of the 360 cycle oscillator. The relationship is best shown in Figure 4, where it will be seen that power input is an approximately linear function of the percentage reduction in curd tension up to a maximum of about 1900–2000 watts. At inputs greater than 2 kilowatts there is no further rise in efficiency. The curve was derived from averages of all samples treated in the oscillator, including both hard and medium curd milks, at 250 gallons per hour and at temperatures above 35° C. The significant average points together with extreme values are as follows:

INPUT	% R AVERAGE	% R EXTREMES
700 watts	25%	5% – 35%
1400 watts	45%	24% – 62%
1900 watts	56%	35% – 72%

If, as in the broken line curves, the hard curd and medium curd values are plotted separately it will be seen that the percentage reduction in the former group is considerably greater than in the latter group. Thus at 1900 watts the extreme low reading in the hard curd group represented a 45 per cent decrease in curd tension as compared with an extreme low of 35 per cent in the medium curd group. This simply means that the final curd values in terms of grams are approximately the same regardless of the original curd hardness, a point of considerable practical importance. Taking the average for all groups (solid curve), the slope between 700 and 1900 watts input is such that approximately 37 watts input is required to bring about a decrease of one per cent in curd tension at the designated velocity (250 gallons per hours). Since the efficiency of the particular oscillator is approximately 47 per cent it follows that roughly 18 watts of acoustic energy must be available in order to bring about one per cent reduction in curd tension.

In the case of the 610 cycle Fessenden oscillator most of the experiments were performed at 1400 watts input. The average reduction in curd tension at 250 gallons per hour in this case was about 34 per cent compared with 46 per cent at 1400 watts in the case of the 360 cycle oscillator. However, the lower order of efficiency obtained at the higher frequency results

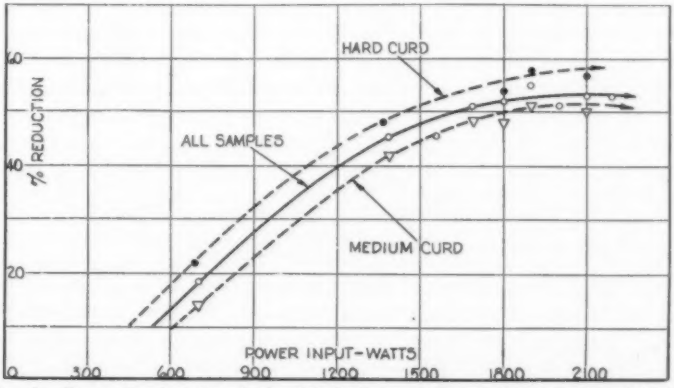

FIG. 4. Curve showing the relationship between % R and the power input to the 360 cycle oscillator with a maintained milk flow of 250 gallons per hour. The solid line represents an average of all types of milk while dotted lines indicate average values obtained in the medium and hard curd groups. All samples were preheated to 50° – 60° C.

in an acoustic output ratio of about 18 watts to each one per cent reduction in curd tension, a figure identical with that obtained at the lower frequency.

In the case of the electromagnetic oscillators, power ratios were not so significant because of the relatively low velocities and consequent high degree of error in measurement and because of the relatively greater influence of uncontrolled variables, such as the amount of included air in the milk. However, the ratio of acoustic output in watts to percentage reduction at a fixed rate of flow seems to be of the same order of magnitude as in the larger oscillators.

D. *Degree of reduction as related to frequency.*

Studies summarized in the above paragraphs relative to the dosage requirements with the different types of oscillators indicate quite conclusively that the frequency of vibration is not a function of the degree of curd tension reduction obtained over the range explored, *i.e.*, from 360 cycles to 3000 cycles. The 3000 cycle oscillator failed to give any appreciable reduction in curd tension, but this fact must be interpreted in terms of the extremely low electrical efficiency of the oscillator. The frequency band explored is so narrow that slight differences may have escaped attention.

E. *Extent of reduction as related to original curd tension.*

As is the case where curd tension is reduced by pressure homogenization, the vibration treatment produces a greater decrease in hard curd than in medium curd milks. The different average values for the two general groups have been indicated above in connection with studies on velocity and energy relationships.

The disparity in amount of reduction naturally implies a tendency for all samples of milk to assume similar actual values in terms of grams curd tension when subjected to identical conditions of handling and treatment. As a matter of actual record in more than 150 samples of milks varying between 28 and 110 grams original curd tension handled under identical conditions the final tension values fell below 18 grams in but 2 instances and above 32 grams in not more than 5 instances.

F. *Degree of reduction as related to fat dispersion.*

The original observations of curd tension reduction in milk were made during the course of efforts to homogenize the butter fat with the 1200 cycle electromagnetic oscillator. At the low velocities of flow possible under the conditions of the experiment it was found that the degree of curd tension reduction was a linear function of the average diameter of fat particles resulting from the dispersive action of the oscillator. The relationship is illustrated in Figure 5 in which the average relative particle

sizes resulting from all individual experiments with the particular oscillator are plotted against the percentage of original curd tension remaining in the treated milk.

On the other hand when the larger oscillators of greater capacity were used no such relationship between average particle size and degree of change in curd texture was found. Indeed microscopic examination of the milk after treatment at 250 gallons per hour with a frequency of 360 cycles repeatedly failed to indicate more than a slight reduction in average particle size although the reduction in curd tension, as shown previously, never amounted to less than 35 per cent and in many case was greater than 60 per cent.

Reductions in average fat particle diameter of the order indicated in Figure 5 should result in proportionate reductions in the cream volume

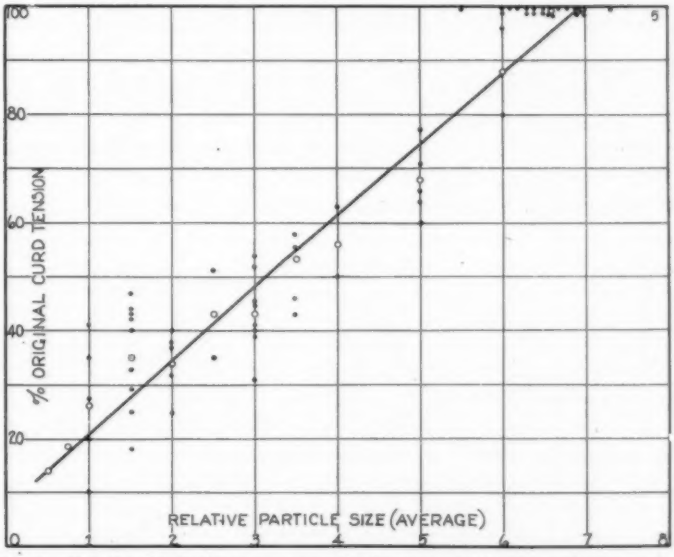

FIG. 5. Relationship between average relative fat particle size and per cent of original curd tension in samples treated at 1090–1140 cycles in small electromagnetic oscillator. Initial average diameter was set at 6–7 to establish the scale. In all cases the rate of flow through the oscillator was low, being restricted by extremely small clearances between reflecting anvil and diaphragm.

and such was found to be the case. Where the particle size was reduced to an average of 1.5 μ or less there was no cream formation even after standing 48 hours at 10°. With an average diameter of 3–4 μ the cream volume was reduced to the extent of about 60 per cent. From this observation in the case of the small 1200 cycle oscillator it was expected that milk

treated in the 360 cycle oscillator would show little if any change in cream volume. Paradoxically the expectation was found to be erroneous. As a matter of fact in most cases, even those in which little change in fat particle diameter could be observed microscopically there was an impairment of cream volume. The fat was slow to rise and the final volume was less than that of the untreated milk by from 25 to 100 per cent. These observations were checked by Doctors Whitaker and Weisberg of the National Dairy Laboratories. In addition Doctor Whitaker determined that the reason for the failure of treated milk to form a cream layer or to separate rapidly lies in a failure of the fat particles to agglomerate normally. No explanation of this latter phenomenon is available at present.

Additional evidence relative to the role of dispersed fat in determination of curd texture was obtained from experiments based on the vibration of skim milk and milk from which the original fat had been partially removed. The samples of skim milk used were obtained from various commercial sources. When treated under the usual conditions (250 gallons per hour, 360 cycles, 2000 watts) the samples showed considerable variation in susceptibility to vibration in so far as curd texture was concerned. In about half of the cases no reduction in tension was recorded while the remainder showed reductions ranging from about 10 per cent up to the average value obtained under similar conditions in whole milk. Figure 6

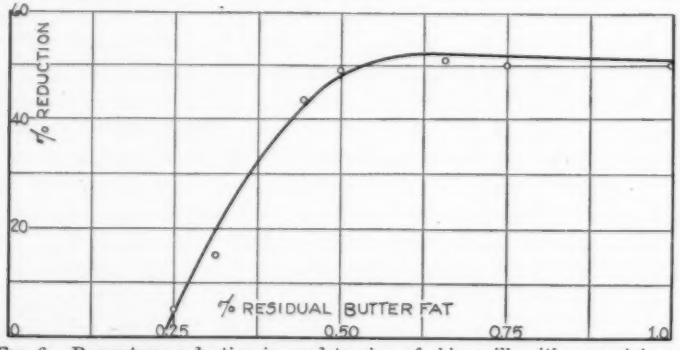

FIG. 6. Percentage reduction in curd tension of skim milk with respect to residual butter fat concentration when treated at 25 gallons per hour, 500 watts in small 1090 cycle oscillator. Temperature 50° C. No reduction was obtained where the fat concentration was less than 0.25 per cent.

indicates the manner in which the percentage reduction in curd tension varied with the concentration of residual butter fat. (The figure is derived from experiments on the 1090 cycle oscillator at 500 watts and a flow of 25 gallons per hour.) With fat percentages less than 0.25 little or no change in curd texture was obtained. From 0.25 per cent to the maximum

of about 0.65 per cent the degree of reduction increased directly with fat concentration. Particularly interesting is the observation that the same order of reduction was obtained at a fat concentration of 0.65 per cent as was observed in whole milk.

As a further check on the role of fat particles in determination of curd texture the following experiment was carried out. A sample of skim milk was centrifuged at high speed to reduce the residual fat to about 0.01 per cent. To this was added 29 per cent cream to bring the fat concentration to values of 0.25, 0.5, 1, 2, 3, 4, and 10 per cent, after which addition the curd tension was measured. To another portion of the skim milk sample was added the same amounts of 29 per cent cream previously homogenized. The dispersion of fat in the second cream sample was such that it contained 1000 times as many fat particles and offered 10 times as much surface as did the unhomogenized cream used in the first series. The accompanying figure (Figure 7) shows the relationship between the percentages of fat in the two cases and the final curd tension values. With homogenized cream approximately the same value was obtained at 0.25

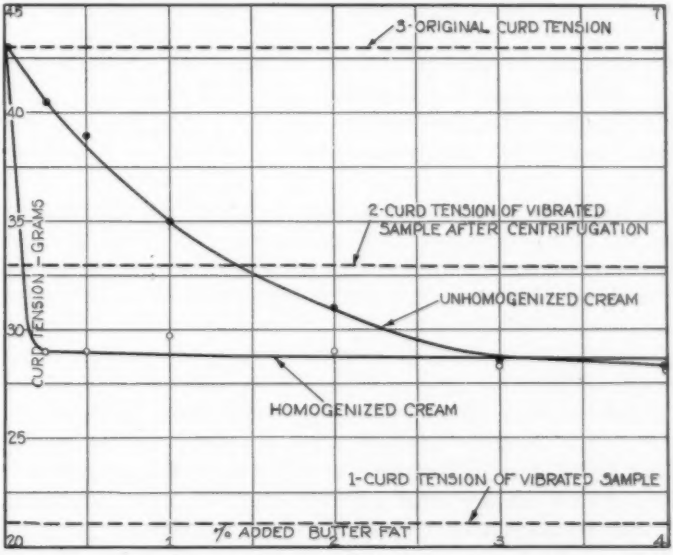

FIG. 7. Curves showing the effect of added butter fat in the form of 29% cream, homogenized and unhomogenized, on the curd tension of a skim milk sample of 0.01% residual fat concentration. The homogenization was such that a particle number ratio of 1000/1 existed between the two cream samples. Horizontal dotted lines indicate (1) the curd tension obtained by vibration of the 3% unhomogenized mixture, (2) the curd tension arrived at by centrifugation of the vibrated sample to the original 0.01% butter fat, and (3) the original curd level of the 0.01% skim sample.

per cent butter fat as at any higher concentration. With unhomogenized cream the drop in curd tension was much less abrupt, the limiting plateau level being attained only after addition of 3 per cent of fat. The number of fat particles present per unit volume of milk is therefore an important function of the curd texture.

It was suspected that increased adsorption and fixation of casein or other polar constituents incident upon the great increase in fat surface available for such adsorption when the particles are subdivided *in situ* either by homogenization or by vibration might play an additional role in the curd tension reduction. To check such a possibility a sample of the same milk used in the experiment above, to which had been added 3 per cent of unhomogenized butter fat in the form of 29 per cent cream, was passed through the small 1200 cycle oscillator at a flow of 25 gallons per hour. The curd tension after treatment was 21 grams as compared with the 29 gram value obtained by simple addition of the butter fat. After the vibration treatment the milk was centrifuged in such a manner as to bring the butter fat value back to the original 0.01 per cent of the basic skim sample. Whereas the initial tension was 43 grams, the final tension after removal of the butter fat subdivided *in situ* was only 35 grams. This fact probably indicates a permanent fixation of part of the originally dispersed casein or calcium caseinate on the enhanced fat surface and its subsequent removal from the milk along with the fat itself. Unvibrated 3 per cent milk when centrifuged was returned to the original curd tension value (43 grams).

From the above experiments its seems to follow that the reductions in curd tension of milk obtained with the larger as well as the smaller oscillator is dependent on either increasing the number of fat globules without reference to increased absorptive surface, or on elimination of casein from the coagulation complex through increased surface absorption and fixation, or both. In any case it seems obvious that the required increase in particle number of available surface may be obtained by subdivision of a relatively small proportion of the total number of particles present in whole milk.

As a further check on this theory and for practical reasons attempts were made to produce by vibration at 360 cycles per second, a soft curd milk in which the cream volume was not impaired. In the accompanying table (Table I) the results of these efforts are set forth. The whole milk in each case was allowed to stand in the holding tank at 10° for from two to four hours during which time gravity separation of cream was accomplished to the extents indicated. The lower four-fifths of the milk was then passed through the oscillator at 250 gallons per hour after heating by means of a water bath to a temperature of 50°. Thus only $\frac{1}{5}$ to $\frac{1}{4}$ of the fat which would normally appear as cream in twenty-four hours was

TABLE I

Protocols of three experiments in which satisfactory reduction in curd tension was obtained without eradication of creaming by partial gravity separation, treatment of the relatively fat free portion, and subsequent addition of the fat rich portion

	TYPE OF SAMPLE	VELOCITY GALS./HR.	FREQUENCY CYCLES/SEC.	POWER INPUT WATTS	CURD TENSION	RELATIVE CREAM VOLUME
EXP. I 4 hours gravity separation	Whole Milk	.....	.....	.....	74	7/16
	Lower 4/5	.....	.....	.....	75	3/16
	Upper 1/5	.....	.....	.....	58	
	Lower 4/5 (vibrated)	250	360	2000	24	
	Vibrated 4/5 plus Upper 1/5	.....	.....	.....	28	9/16
EXP. II 2 hours	Whole Milk	.....	.....	.....	70	8/16
	Lower 4/5	.....	.....	.....	72	5/16
	Upper 1/5	.....	.....	.....	55	
	Lower 4/5 (vibrated)	250	360	2000	25	
	Vibrated 4/5 plus Upper 1/5	.....	.....	.....	31	7/16
EXP. III 4 hours	Whole Milk	.....	.....	.....	66	7/16
	Lower 4/5	.....	.....	.....	75	2/16
	Upper 1/5	.....	.....	.....	33	
	Lower 4/5 (vibrated)	250	360	2000	27	
	Vibrated 4/5 plus Upper 1/5	.....	.....	.....	29	9/16

exposed directly to the vibration. The supernatant cream layer was added to the treated residuum immediately but was not passed through the oscillator while the power was on. In two of the three experiments the cream volume after twenty-four hours was slightly less than normal. In the third case the volume was rather markedly increased. This last result was doubtless due to the fact that the milk was allowed to stand for a shorter time before treatment of the "skim" layer thus resulting in vibration treatment of a larger proportion of the butter fat. The creaming situation was comparable with what may be expected from partial homogenization in a commercial pressure device.

The significant indication of the above experiment is that dispersion of a relatively small part of the total butter fat content of whole milk results in as great reduction in curd hardness as does vibration of the whole milk. From this it follows that the production of soft curd milk by vibration without consequent elimination of the creaming property is practicable.

G. *Degree of reduction as related to mechanical factors.*

Figure 8 indicates the manner in which the extent of curd tension reduction varied with variations in clearance between the reflecting anvil

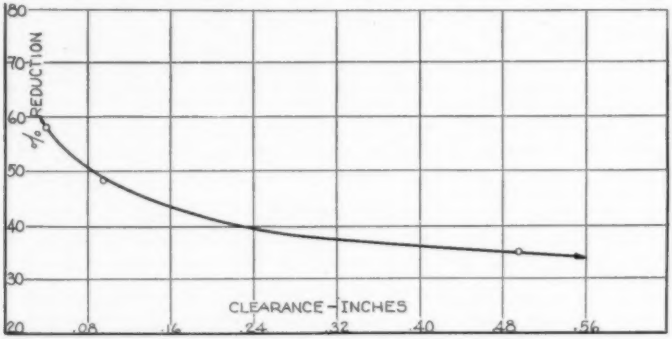

FIG. 8. Curve showing relation between anvil clearance (thickness of exposed milk layer) and % R in 360 cycle oscillator operated at 1900 watts with a milk flow of 250 gallons/hour. The standard flow could not be attained with clearances less than 0.04 in.

and the diaphragm. All points represent averages derived from samples subjected to identical treatment with respect to power input (1900 watts), velocity (250 gallons per hour), temperature (50°), and frequency of vibration (360 cycles per sec.). Under the conditions of the experiment it was impossible to maintain an adequate flow without resorting to pressures above atmospheric at clearances below .040 inches. It is obvious that greater efficiency is attained when the layer of milk between the rigid and the actively vibrating members is thin. The most practicable clearance was found to be about .100 inch, while .500 inch seems to represent a limit beyond which there is very little further decrease in effectiveness.

It should be recalled that the averages used in the previous relationships (velocity, power, et cetera) are based on experiments covering the entire range of clearances between .040 and .500 inches. This accounts for part of the wide variation in curd tension observed under otherwise identical conditions of exposure.

Other variations in the mechanical set-up of the large Fessenden oscillator (360 cycle) such as scoriation of anvil or diaphragm or both to increase turbulence have not been found to exert any measurable influence on efficiency of the apparatus.

In addition to the above mentioned physical experiments certain biological tests have been undertaken with the vibrated milk. These are not completed as yet but indicate tentatively that soft curd milk produced by vibration differs in no qualitative respect from the similar product produced by pressure homogenization. This in itself furnishes further indica-

tion that the mechanisms in the two cases are similar and that the alteration of curd in both cases is dependent upon increase in adsorptive surface and consequent shift in the calcium/casein equilibrium by fat dispersion.

The flavor and odor of the vibrated milk has been found normal. Furthermore no precipitate of any consequence has been observed in the treated milk even after forty-eight hours of standing.

DISCUSSION

The majority of published studies on the factors influencing the curd texture of milk have concerned themselves with the causes of variations in normal unaltered milk. In general these investigations have attempted to show that the curd texture is primarily related to the concentration and distribution of casein, soluble calcium, and to a limited extent, butter fat. The role of calcium can scarcely be considered inasmuch as a great excess of calcium chloride is normally added before the Hill test is made.

A complete exposition of the theoretical implications of the experiments recorded in this paper cannot be attempted here. However, the results seem to demonstrate that the sonic vibration acts directly on the butter fat of the milk causing a more complete dispersion and consequently increasing the specific surface. Thus a larger proportion of the available protein is adsorbed and fixed in such a way that it no longer influences the coagulation complex.

In addition to the removal by fixation of a portion of the total protein from the serum, the dispersion of fat seems to affect the curd texture directly, probably by providing points of weakness in the final curd matrix. This mechanical influence is apparently negligible as compared with the more indirect factor of increased surface. Reductions obtained by the simple addition of butter fat in the form of cream to skim milk never amount to more than 15–18 grams no matter what the initial tension of the skim sample, the percentage of added fat, or the state of subdivision of the fat. Fat added in this way does not provide additional adsorptive surface so its effect is probably entirely mechanical. The situation is different in every respect except that of particle number from that obtaining when the fat is subdivided *in situ*.

The evidence favoring the theory that the curd tension reducing action of sonic vibration is entirely a dispersive action on the butter fat may be summed up as follows:

1. The curd tension of skim milk of less than 0.2 per cent butter fat is not changed by vibration.

2. The curd tension of milk containing more than 0.25 per cent butter fat may be reduced by vibration at a temperature higher than the melting point of butter fat but no change can be effected below that temperature.

3. The reduction of curd tension in skim milk by addition of heavy cream is proportional to the number of added fat particles and bears no direct relationship to the actual fat concentration.

4. The vibratory subdivision of butter fat *in situ* results in a permanent lowering of the curd tension even after the fat has been removed by high speed centrifugation. Thus the adsorptive action of the increased fat surface is demonstrated to be an important factor.

The failure to observe any appreciable degree of fat dispersion in milk treated in the 360 cycle oscillator may not be admitted as contrary evidence. It must be remembered that the subdivision of as little as 0.25 per cent of butter fat in a milk sample brought about as great a reduction in tension as was accomplished by the action of the vibrator on whole milk. Under the crude conditions of observation and measurement of particle diameters subdivision of less than one-eighth of the total number of particles would have little influence on the average particle values recorded. It should be pointed out that there was always more Brownian movement to be observed in the treated samples than in the control milk. Incidentally the average particle diameters used throughout this report represent only relative values since calibration of the micrometric apparatus was carried out very roughly. Knowledge of the absolute values would be of no importance in this study.

From a practical viewpoint the sonic method of producing curd tension reductions in milk is of interest. The apparatus is simple, both in construction and operation, relatively inexpensive in initial cost and in operation, and easily conformable to the operating requirements of the average milk plant. The simple construction of the vibrator unit makes it desirable from the viewpoint of the sanitation engineer. In addition the method can be adapted either to markets in which a normal cream volume is demanded, or to those in which the sale of homogenized milk is the usual and accepted practice.

SUMMARY

Reduction in the curd tension of milk was accomplished by flowing the fluid in a thin layer over electromagnetically driven diaphragm sources of intense sonic vibration.

A study was made of the curd reducing effectiveness of oscillators operating at 1100, 1200, 2160, 3000, 610, and 360 cycles as related to original curd tension of the milk, temperature, time of exposure (velocity of flow), acoustic energy output, and variations in the mechanical features of the apparatus.

The percentage reduction in curd tension was greatest in hard curd (60 grams and more) milks. Final curd values approached a constant level in the soft curd range no matter what the original curd texture.

No reduction in curd tension was obtained in milk treated below 18° C. and very little at temperatures below the melting point of butter fat.

It was found that one of the oscillators (360 cycle) was most efficient when the milk flow was maintained at 250 gallons per hour. With a sound output of about 900 watts more than 50 per cent reduction was attained.

With the 360 cycle oscillator the degree of reduction in curd tension was found to bear a direct linear relationship to the power input up to 2000 watts when the velocity was 250 gallons per hour. This represents an output of about 18 watts per one per cent decrease in tension. Other oscillators at different frequencies showed much the same effectiveness with equivalent outputs per unit volume of milk. Hence differences in frequency were found to be negligible within the range explored.

A direct relationship was found to exist between degree of fat dispersion and degree of curd tension reduction. The increased number of fat particles was shown to influence curd texture by weakening the curd matrix and by providing increased adsorptive area on which protein was fixed.

Since but a small proportion of the total fat in milk need be finely subdivided to reduce the curd tension, a method was devised for producing soft curd milk by vibration without impairing the final cream volume.

ACKNOWLEDGMENTS

I am indebted to Mr. R. L. Williams and Mr. E. W. Smith of the Submarine Signal Company, Boston, Massachusetts, for material and technical assistance with the oscillators used in this investigation, and to Doctors Shrader, Whitaker and Weisberg of the National Dairy Products Corporation for advice and assistance in the field of dairy technology. In addition grateful acknowledgment is tendered to the Deerfoot Farms Dairies of Southboro, Massachusetts, which supplied most of the milk used in the experiments.

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THE INFLUENCE OF FOOD FAT OF VARYYING DEGREES OF UNSATURATION UPON BLOOD LIPIDS AND MILK FAT

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For several years this laboratory has been engaged in an investigation of the secretion of milk fat by studies of the interrelationships between the kind and amount of food fat, the distribution and character of the blood lipids and the nature and amount of the fat secreted. Both cows and goats have been used in these studies. The present paper reports a continuation of this work and describes results obtained where the distinguishing feature of the rations was the degree of unsaturation of the fat component.

Holstein cows were fed in alternate periods rations containing fat of high and low iodine number, by varying the character of the grain mixture. The same ingredients were used in each mixture with the exception that 10 per cent of ground flaxseed was included in the mixture designed to furnish fat of high iodine number and that 30 per cent of cocoanut oil meal was present in the mixture supplying the fat of low iodine number. The other ingredients were varied in amount to provide 20 per cent of protein and the same content of total digestible nutrients in both mixtures. The cocoanut oil meal mixture contained 6 per cent of fat having an iodine number of 26, while the other mixture contained 6.5 per cent of fat with an iodine number of 137.

Each cow was fed the same amount of mixed hay and silage throughout the experiment, but the grain allowance was varied in accordance with production. On the basis of the amounts of each feed fed, its fat content and the iodine number of this fat, the fat intake and its iodine number for the ration as a whole were calculated. The feeding system was as follows:

Cow	Period 1	Period 2	Period 3
	20 days	*20 days*	*10 days*
E	Low I. No. ration	High I. No. ration	Low I. No. ration
C	High I. No. ration	Low I. No. ration	High I. No. ration

The changes in the ration from one period to the next were made abruptly.

The cows were milked twice a day. The fat and its iodine number were determined on two-day composites, periodically throughout the experiment. Immediately prior to a change of ration and for four or five days thereafter these determinations were made on the composite of each day's production. Blood samples were taken from the jugular vein three times in each period. The plasma was used for the determination of total lipids and their iodine

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number, lipid phosphorus and cholesterol. The methods were the same as those used previously (1).

RESULTS

The data showing the changes in the character of the milk and blood fat are plotted in charts 1 and 2. The striking feature of these data is the

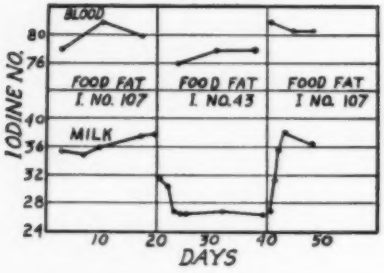

CHART 1. Iodine numbers of plasma total lipids and of milk fat. Cow C.

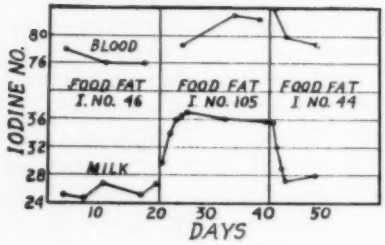

CHART 2. Iodine numbers of plasma total lipids and of blood fat. Cow E.

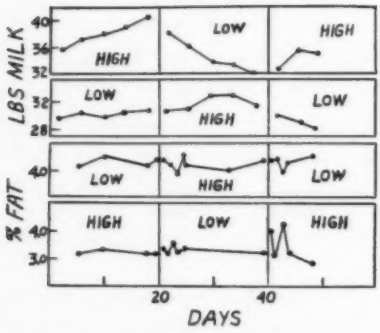

CHART 3. Milk yields and fat percentages, Cows C and E. (High and low refer to the iodine numbers of the fat intake.)

rapidity of the change in the character of the milk fat following a change in the food fat. The last determination for a given period was made on a sample composited from the milking at 4 p. m. and the milking at 4 a. m. At the following noon feeding the cow received her first intake of the changed ration and the first determination thereafter was made on the composite of the milk obtained that evening and the following morning. Thus the production on which the first determination was made following a change in

ration represented milk secreted during 8 hours on the previous ration and during 16 hours on the new.

The data for cow C in chart 1 show that the iodine number dropped from a value of 38 prior to the change to a value of 32 for the first determination thereafter. Further marked drops are revealed in the following two 24 hour composites to a level which remained practically constant for the remainder of the period. When this cow was changed back to the ration of high iodine number, no marked change in the fat secreted was noted at the first determination, but succeeding 24 hour composites revealed rapid rises to a maximum level on the fourth day after the change. The curve in chart 2 for cow E, which was fed the two rations in reverse order, shows a similar picture. A marked rise is noted immediately after the change to the ration of high iodine number and in the two succeeding determinations, with little change after the third day. Restoration of the original ration was followed by a rapid drop to a minimum value on the fourth day.

It is well understood from many experiments that milk fat can be qualitatively modified by the food fat, but the rapidity of the changes here obtained and the short time required for their completion are especially noteworthy, in view of the time required for food to pass through the digestive tract of the ruminant and in view of current ideas as to the intermediary metabolism of fat prior to its deposition or secretion. Upon feeding butter to a cow which had received no food other than a little hay during the previous 24 hours Gage and Fish (2) found no change in the chylomicron curve up to the fifth hour. Peaks in the absorption curve were found at the sixth hour and intermittently thereafter up to the nineteenth. There were intervening periods in which little or no absorption was indicated. It may be presumed that the absorption of fat ingested in a mixed ration of natural feeds, as used in the present experiment, would be slower than of butter. Moore and Winter (3) have reported that the inert material, iron oxide, commenced to appear in the feces of the cow only after 10 hours, that the high point of excretion was reached after 33 hours and that as long a time as 156 hours elapsed before all the material was excreted.

It is clear that it may be a matter of several hours before the absorption of ingested fat begins in the ruminant, and that it is a gradual and intermittent process which requires an extended period for its completion. Once the fat is absorbed its metabolism involves various intermediary changes in which several organs, notably the liver, have been ascribed a role. While many later experiments throw doubt on the theory of Soxlet that the food source of milk fat is first deposited in the fat depots, as the sole explanation of the course of fat metabolism in lactation, there is ample evidence that the depots do play a role. The recent work of Peterson, Palmer and Eckles (4) suggests that the blood precursor of milk fat is first transformed into a glandular fat intermediate in character between body fat and the fat of milk.

Finally it must be recognized that the modification of the secreted fat under the influence of the diet occurs in opposition to the normal tendency of the gland to secrete a product of constant composition.

The rapidity with which this modification was found to occur in the present studies indicates that the course of metabolism through which the absorbed fat passes after absorption must be short or that the various processes must take place with great speed. Both the magnitude and rapidity of the changes in the character of the milk fat furnish evidence opposed to the widely quoted conclusion of Gage and Fish (2), based on their studies with stained fats, that in the cow milk is derived only to a small degree from the fat in the food.

In view of the changes of the milk fat under the influence of the food, one would expect similar changes in the blood and the data given in the charts for the iodine numbers of the total lipids of the blood plasma indicate this to be true. The determinations are too few to show the exact course of the change in the blood following a change in the diet, but the results do indicate an interrelationship between the degree of saturation of the blood lipids, and that of the food fat on the one hand and that of the milk fat on the other. The extent of the change in the blood, however, is smaller than in the food or milk. Because of the large volume of blood and its rapid circulation, small changes in it might well be reflected in large changes in the milk. Further it must be borne in mind that the blood values represent the changes in the total lipids and that changes of larger magnitude might have been found in the particular fractions which are the actual precursors of milk fat.

Similar changes in the degree of saturation of the blood lipids were observed in our studies (5) of the effect of the ingestion of cod liver oil on the composition of blood and milk. The feeding of this highly unsaturated oil, which caused a rise of approximately 30 per cent in the iodine number of the milk fat, was accompanied by a 10 to 20 per cent rise in this value for the blood lipids. We have also made similar observations on goats (unpublished).

The data for total lipids, lipid phosphorus and cholesterol showed no marked nor consistent changes in the amounts of these lipids in the blood plasma under the influence of the changes in the character of the fat fed. These data, coupled with the fact that the fat intakes were nearly alike in the different periods, indicate that neither the level of fat fed nor the level of any lipid in the blood was a factor in the changes in the character of the fat secreted.

The data for milk yield and fat percentage are presented in chart 3. In general the trend of milk yield is upward with the ration containing the fat of high iodine number and downward in the case of the other ration. Such an observation with only two animals and over brief periods can have no significance other than to suggest a question which may deserve further

study. The curves for fat percentage show little change other than daily fluctuations following the changes of ration. There is no evidence that the change in the character of the food and blood fat had any influence on the percentage of fat in the milk, although it did markedly change its character. This observation is of interest in comparison with the data obtained with the cod liver oil (5), suggesting that the effect of the oil in lowering fat percentage cannot be due to its high degree of unsaturation.

SUMMARY

The course of the changes in the iodine numbers of the blood lipids and milk fat was followed with cows fed in alternate periods rations containing fats of a high and low degree of unsaturation. In half of the cases a marked change in the iodine number of the milk was noted in a composite of the milk secreted during the first 18 hours following a change in ration, and in all cases within the next 24 hours, the maximum change being attained within three or four days. Corresponding but less marked changes were found in the blood. The data reveal a close relationship between food fat and milk fat, and indicate that the course of fat metabolism in lactation must be a very direct one or that the various processes must take place very rapidly.

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THE AGE THICKENING OF SWEETENED CONDENSED MILK III. EFFECT OF REACTION AND CHANGES IN THE ELECTRICAL CONDUCTIVITY DURING MANUFACTURE AND AGING*

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In a sensitive colloidal system such as milk small changes in the various ionic concentrations are likely to exert a great influence on the stability of the system. Since the electrical conductivity of milk depends upon the various ions present and the hindering effect of the non-electrolytes, it is reasonable to expect that any changes occurring in the ionic equilibrium and the concentration of the non-electrolytes during the manufacture and aging of sweetened condensed milk would be reflected in a change in the electrical conductivity. It is a matter of common experience that an increase in acidity almost invariably decreases the heat stability of milk. With these facts in mind, electrical conductivity and hydrogen-ion concentration measurements were made during the preparation and aging of several batches of sweetened condensed milk. The different batches varied in their stability toward age thickening.

EXPERIMENTAL METHODS

The pH measurements in these trials were made at 25° C. (77° F.) with the quinhydrone electrode and a saturated calomel half-cell.

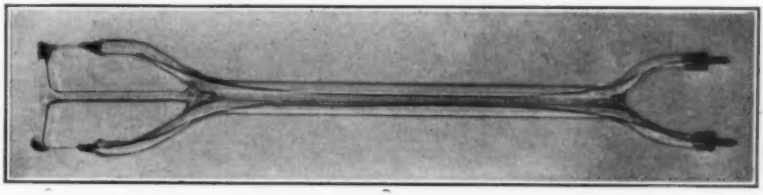

FIG. 1. SPECIAL ELECTRODE USED IN MEASURING THE ELECTRICAL CONDUCTIVITY OF SWEETENED CONDENSED MILK.

Conductivity measurements were made according to the Kohlrausch method using a Leeds and Northrup microphone hummer, a Leeds and Northrup precision Wheatstone bridge and tunable telephone receivers. A special type of electrode was used so that it could be inserted into the tube of condensed milk when making a measurement without it being necessary

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TABLE 1

Changes in reaction and electrical conductivity during the manufacture and aging of sweetened condensed milk

BATCH	I			II			III			IV			V		
	Con.* $\times 10^4$	pH	Vis.″	Con.* $\times 10^4$	pH	Vis.″	Con.* $\times 10^4$	pH	Vis.″	Con.* $\times 10^4$	pH	Vis.″	Con.* $\times 10^4$	pH	Vis.″
Raw Milk	61.3	6.63		69.8	6.27		61.3	6.62		69.8	6.67		69.8	6.33	
Milk plus Sugar	34.9	6.55		40.5	6.24		40.5	6.57		34.5	6.60		44.2	6.28	
After Forewarming		6.49		40.5	6.26		37.3	6.57		44.2	6.47		48.69	6.20	
After Condensing	7.42	6.10	7.4	8.46	5.87	19.8	5.1	6.14	8.7	6.53	6.14	6.2	8.46	5.85	7.4
Storage															
1 Day	6.60	5.62	112.2	7.31	5.98	416.6	4.5	6.13	36.2	5.27	6.00	14.8	7.70	5.77	18.6
2 Days															
4 "							4.7	6.16	273.1						
5 "			792.2	6.75	5.98	**									
6 "															
7 "													6.47	6.03	568.0
8 "							4.9	6.27	740.1	4.97	6.34	69.3			
9 "				7.19	6.14										
10 "			568.0												
11 "															
12 "							4.47	6.27	1190.0						
14 "							5.03	6.00	773.0						
15 "				6.85	6.18										
16 "	6.17	6.31	525.7												
17 "														5.90	660.0
18 "										6.80	6.22	28.4			
19 "															
20 "	6.43	6.33	1088.0												
22 "															
26 "	6.43	6.30	810.0												
27 "							4.28	6.25	1900.0						
30 "															
96 "													7.84	5.95	‡
101 "										5.47	5.91	1116.0			
106 "							4.79	6.18	‡						

* Conductivity.
** Solid.
″ Viscosity.
‡ Too viscous.

Forewarming temperature, 88° C. (190.4° F.) for 10 minutes.
Storage temperature, 37° C. (98.6° F.).

TABLE 1—*(Continued)*

Changes in reaction and electrical conductivity during the manufacture and aging of sweetened condensed milk

BATCH	VI			VII			VIII			COW 72			COW 71		
	Con.* $\times 10^6$	pH	Vis.″	Con.* $\times 10^6$	pH	Vis.″	Con.* $\times 10^6$	pH	Vis.″	Con.* $\times 10^6$	pH	Vis.″	Con.* $\times 10^6$	pH	Vis.″
Raw Milk	72.1	6.58		67.2	6.45		66.7	6.42		63.8	6.64		72.7	6.52	
Milk plus Sugar										41.8	6.59		48.3	6.42	
After Forewarming	40.2	6.53		46.8	6.40		37.8	6.38		40.7	6.48		48.3	6.27	
After Condensing	6.69	6.01	22.3	5.02	5.86	38.4	5.87	5.97	44.6	4.53	6.08	643.0	9.74	5.77	9.9
Storage															
1 Day				4.76	5.87	♮									
2 Days							5.29		1850.0	4.52	6.05	♮	6.38	5.76	311.8
4 "															
5 "	6.20	6.05	♮				5.21	5.91	♮	5.20	6.12				
6 "				4.45	5.91								6.97	5.78	♮
7 "															
8 "	6.57	5.87													
9 "										6.37	6.15	**			
10 "															
11 "	6.60	5.60													
12 "															
14 "							5.48	6.07							
15 "															
16 "															
17 "															
18 "	6.74	6.06													
19 "				4.96	6.09										
20 "															
22 "													6.10	5.88	
26 "										4.48	6.15				
27 "															
30 "	6.58	6.21													
96 "															
101 "															
106 "															

* Conductivity.
** Solid.
″ Viscosity.
♮ Too viscous.

Forewarming temperature, 88° C. (190.4° F.) for 10 minutes.
Storage temperature, 37° C. (98.6° F.).

to remove the milk from the tube in which it was stored. This electrode is shown in figure 1. Conductivity measurements were made at 37° C. (98.6° F.), the temperature of storage, using a constant temperature water bath to hold the tubes while the measurements were being made.

The method of making the condensed milk and measuring the viscosity has been described in a previous paper (1).

CHANGES IN REACTION AND ELECTRICAL CONDUCTIVITY DURING THE MANUFACTURE AND AGING OF SWEETENED CONDENSED MILK

Roadhouse and Koestler (2) found the electrical conductivity of the milk from three different cows to be 41.79×10^{-4}, 39.37×10^{-4} and 44.09×10^{-4} mhos. Palmer and Dahle (3) report the average specific conductivity of four determinations for fresh, pasteurized milk as 54.7×10^{-4} mhos at 25° C. Jackson, McNab and Rothers (4) found that the electrical conductivity of bulk milk at Melbourne, Australia, during the months of November, December, February and March varied between 54.9×10^{-4} and 58.7×10^{-4} mhos. These latter investigators also found that the rapid decreases in conductivity as sweetened condensed milk was concentrated could be used as a test for determining the end of the condensing period.

The electrical conductivity and pH during the preparation and aging of 10 batches of sweetened condensed milk is shown in table 1. Eight of these trials were made on mixed milk obtained from the raw milk holding vat of the University Creamery, while two were from individual cows as designated in the table.

ELECTRICAL CONDUCTIVITY

The fresh milk used in these experiments varied in electrical conductivity from 61.3×10^{-4} to 72.7×10^{-4} mhos. However, it is to be remembered that these readings were made at 37° C., which accounts for the values being higher than those previously reported. There appears to be no correlation between the electrical conductivity of the fresh milk and the stability of that milk toward age thickening when made into sweetened condensed milk. Neither is there any correlation between the electrical conductivity during aging and the thickening of the milk. The average conductivities of these 10 trials are plotted in figure 2. The addition of sucrose equivalent to 18.75 per cent of the raw milk caused an average decrease in conductivity from 67.48×10^{-4} to 40.7×10^{-4} mhos. After forewarming at 88° C. (190.4° F.) for 10 minutes there was a slight decrease in conductivity, followed by a great decrease during the condensing. The average conductivity of all ten samples of milk when the condensing was complete was 6.78×10^{-4} mhos. These changes in conductivity are comparable to the results obtained by Jackson, McNab and Rothers (4).

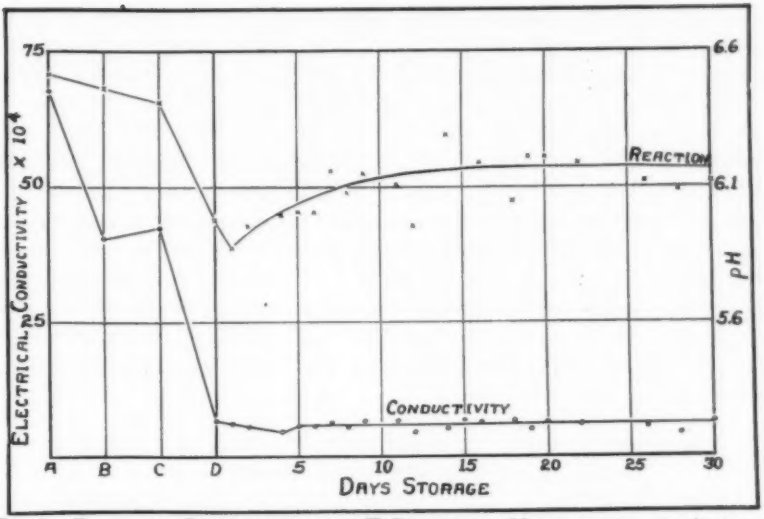

FIG. 2. ELECTRICAL CONDUCTIVITY AND pH DURING THE MANUFACTURE AND AGING OF SWEETENED CONDENSED MILK.

A—raw milk.
B—raw milk plus sucrose.
C—after forewarming at 88° C. (190.4° F.) for 10 minutes.
D—after condensing.

During the first few days of aging there is a slight decrease in conductivity. In every case where the sample was tested at the end of one day this decrease was apparent. After this initial decrease the value rises slightly and appears to remain constant during the aging period. Samples held for over 100 days at 37° C. (98.6° F.) showed no significant change in conductivity.

HYDROGEN-ION CONCENTRATION

The magnitude of the changes in reaction during the manufacture and aging of the milk as shown in table 1 appears to be about the same regardless of the tendency of the milk to thicken or the original acidity of the fresh milk. However, where the pH of the milk was low, as for example in sample II, the milk thickened very rapidly, while other batches condensed during that time of the year but with a higher pH were much more stable. Nevertheless, if the milk is originally unstable, the fact that the pH is normal for fresh milk does not mean that the milk will not thicken rapidly. In other words, the original stability of the milk must be considered in conjunction with the effect of reaction.

The average changes in reaction calculated from table 1 are plotted in figure 2. The average values for the reaction during aging were obtained by determining the increase or decrease in pH at the time of measurement

from what the value was immediately after condensing. If the pH measurements of all samples had been made at the same intervals of time during the aging the average values would have been more satisfactory than it is where, in some instances, only one or two samples were tested.

The reaction of the raw milk used varied from pH 6.27 to 6.67. The addition of 18.75 per cent sucrose caused an average decrease in the pH of 0.05; a further decrease of 0.05 pH was obtained by forewarming to 88° C. (190.4° F.) for 10 minutes. At the end of the condensing period the pH had dropped considerably, as an average, from pH 6.51 to pH 5.98. For a short time during storage at 37° C (98.6° F.) one or two days in most trials, there was a further slight decrease in pH and then a gradual rise of about 0.2 pH after which the reaction remained fairly constant during the aging. Samples held for longer than 100 days at this high temperature showed no appreciable change in reaction.

EFFECT OF CHANGING THE REACTION OF THE FRESH MILK ON THE SUBSEQUENT THICKENING OF THE CONDENSED MILK

In the previous trial it was noted that samples of raw milk with a low pH exhibited a greater tendency toward age thickening. In this trial lactic acid and sodium hydroxide were used to adjust the reaction of the fresh milk so that there would be a difference in pH of about 0.1 between batches. This trial was made during the month of May, 1933, when the milk was originally unstable and a forewarming temperature of 88° C. (190.4° F.) for 10 minutes was used. The results of this trial are shown in table 2.

TABLE 2

Effect of reaction on the age thickening of unstable milk

TITRATABLE ACIDITY	0.12%	CONTROL 0.15%	0.155%	0.16%
pH of the Original Milk	6.86	6.72	6.60	6.50
Days		*Viscosity in Poises*		
0	4.9	4.9	4.9	4.9
2	8.6	137.6	312.5	*
4	13.6	1300.0	*	
7	17.3**	*		
9	30.7			
14	95.9			
18	359.5			
24	2812.0			

* Too viscous to measure.

** Visible fat separation.

Lactic acid and sodium hydroxide used to adjust reaction.

Forewarming temperature 190.4° F. for 10 minutes.

These results with unstable milk show conclusively that a decrease in the pH causes the milk to thicken very rapidly during storage, while increasing the pH makes the milk more stable toward age thickening.

Changing the reaction of stable milk has less influence on age thickening than changing the reaction of unstable milk. However, the trend of the influence is the same for both types. The results of a trial on stable milk during March, 1934, are shown in table 3.

TABLE 3

Effect of reaction on the age thickening of stable milk

pH OF ORIGINAL MILK	6.86	CONTROL 6.63	6.47	6.32
Days	*Viscosity in Poises*			
0	6.2	6.2	6.2	6.2
3	7.4	22.9	539.8	*
7	9.9**	30.6	407.6	
10	13.6	33.5	309.1	
14	16.1	30.6	273.1	
18	25.8	30.6	525.7	

Lactic acid and sodium hydroxide used to adjust reaction.

* Too viscous to measure.

** Visible fat separation.

Sucrose, 44.1%; fat, 7.75%; milk solids-not-fat, 19.87%.

Forewarming temperature 190.4° F. for 10 minutes.

In the trials shown in tables 2 and 3 the pH of the milk was increased by the addition of sodium hydroxide. The data in table 4 were obtained by dividing 32 pounds of raw milk into four 8-pound batches. The first served as a control; to the second was added 1 gram of sodium bicarbonate; to the

TABLE 4

Effect of reaction on the age thickening of unstable milk

TO 8 LBS. MILK	CONTROL	1 GRAM $NaHCO_3$	1 GRAM $Ca(OH)_2$	1½ GRAMS CA LACTATE
pH after Forewarming	6.29	6.48	6.62	6.31
Days	*Viscosity in Poises*			
0	18.6	6.2	6.2	21.5
1	584.0	11.6	11.6	2230.0
2	2205.0	14.8	16.7	*
4	*	19.4**	22.3**	
6		25.8	22.3	
12		39.0	16.75	
19		163.2	25.8	

* Too viscous to measure.

** Visible fat separation.

Forewarming temperature 190.4° F. for 10 minutes.

third, 1 gram of calcium hydroxide, and to the fourth, 1½ grams of calcium lactate. In this trial the pH was determined after the sugar had been added and the milk forewarmed. This accounts for the lower readings than in the two previous experiments shown in tables 2 and 3. The condensed milk made from the batches containing the sodium bicarbonate and the calcium hydroxide were so thin that there was visible fat separation in both after 4 days of storage. From these results it seems to appear that the reaction is the governing factor and that whether the alkali contains sodium or calcium is immaterial.

Tables 5 and 6 show the effect of adding various amounts of sodium bicarbonate to two unstable milks which differed in their rates of thickening. It may be seen that small additions have a very marked effect; a change in the pH of only 0.1 produced very noticeable stabilizing effects. There is

TABLE 5

Effect of various amounts of sodium bicarbonate on unstable milk

TO 8 LBS. MILK	CONTROL	¼ GRAM $NaHCO_3$	½ GRAM $NaHCO_3$	1 GRAM $NaHCO_3$
pH after Condensing	6.01	6.012	6.05	6.18
Days	*Viscosity in Poises*			
0	22.3	21.5	21.5	16.28
5	*	865.0	501.0	25.8
8		*	*	64.4
11				138.8
18				668.0
30				*

* Too viscous to measure.

Forewarming temperature 190.4° F. for 10 minutes.

TABLE 6

Effect of various amounts of sodium bicarbonate on unstable milk

TO 8 LBS. MILK	CONTROL	¼ GRAM $NaHCO_3$	½ GRAM $NaHCO_3$	1 GRAM $NaHCO_3$
pH after Forewarming	6.43	6.46	6.48	6.54
Days	*Viscosity in Poises*			
0	7.4	6.2	4.94	4.94
2	125.0	28.4	19.42	7.4
5	668.0	184.0	125.0	11.14**
8	1190.0	422.0	347.2	19.42
12	2060.0	773.0	549.0	50.1
17	*	1933.0	1362.0	173.5

Sucrose, 44.1%; fat, 7.81%; milk solids-not-fat, 19.4%.

* Too viscous to measure.

** Visible fat separation.

Forewarming temperature 190.4° F. for 10 minutes.

danger in adding too much sodium bicarbonate in that the milk will be so thin that the fat will separate during storage. An addition of 60–125 grams (approximately 2–4 oz.) per 1,000 pounds of raw milk is sufficient to stabilize unstable milk toward age thickening. The hydrogen-ion concentration measurements in table 5 were made on the finished product while those shown in table 6 were made after forewarming but before condensing.

The addition of sodium bicarbonate before forewarming was found to be more effective in preventing age thickening than adding it to the finished product as shown in table 7.

TABLE 7

Effect of adding sodium bicarbonate to unstable milk after condensing

TO 8 LBS. MILK	CONTROL	A	B
pH after Forewarming	6.62	6.94	
Days	*Viscosity in Poises*		
0	14.8	7.4	7.4
3	*	13.6	19.8
5		11.55	64.4
17		16.75	766.0

A 3 grams of sodium bicarbonate added to the milk before forewarming.
B 3 grams of sodium bicarbonate added to the finished product.
* Too viscous to measure.
Forewarming temperature 190.4° F. for 10 minutes.

EFFECT OF FOREWARMING TEMPERATURE ON THE CHANGE IN REACTION

Samples from the same batch of raw milk were forewarmed with sucrose for 10 minutes at the temperature designated in table 8. As the temperature

TABLE 8

Effect of forewarming temperature on reaction

TEMPERATURE OF FOREWARMING	131° F.	180° F.	203° F.	244° F.
	pH	*pH*	*pH*	*pH*
Fresh Milk	6.60	6.60	6.60	6.60
Milk and Sugar	6.55	6.55	6.55	6.55
After Forewarming	6.55	6.53	6.48	6.45

of forewarming increased the pH was lowered, but these changes cannot be correlated with the great difference in stability caused by various forewarming temperatures as shown in the previous paper (5).

DISCUSSION

This work has definitely shown that small changes in the reaction of the raw milk exert a marked effect on the subsequent thickening of the condensed milk. Decreasing the pH causes a more rapid thickening, while increasing the pH decreases the tendency to thicken. The magnitude of

the effect due to the reaction seems to depend upon the original stability of the milk as well as other factors which affect the rate at which the milk will thicken. The conclusion of Rogers, Deysher and Evans (6) that changes in the reaction within reasonable limits have no significant effect upon the subsequent thickening was based upon a trial with very stable milk. With a forewarming temperature of 63° C. (145.4° F.) their control batch showed practically no increase in viscosity when stored at 30° C. (86° F.) for 30 days. Had their forewarming conditions been more favorable for the rapid thickening of the milk their results would, no doubt, have shown that reaction is an important factor.

It was found that for a short time after condensing, one or two days in most instances, there was an average decrease in pH and then a gradual rise of about 0.2 pH, after which the reaction remained fairly uniform during the aging period. This same general trend holds in the case of electrical conductivity. For a few days after condensing there was a gradual drop in electrical conductivity and then a slight rise, after which the value remained constant during the aging period.

From these results it appears that a storage period of several days at 37° C. (98.6° F.) is required for ionic equilibrium to be reached and that after it has been reached it remains unchanged during the aging. This shift in equilibrium appears to occur independently of the tendency of the milk to age thicken. However, instances have been observed where samples thickened very rapidly at first and then for a period showed a progressive decrease in viscosity upon further aging.

CONCLUSIONS

Increasing the acidity of the raw milk causes the sweetened condensed milk to thicken more rapidly during storage, while decreasing the acidity makes a more stable product. With unstable milk a change of 0.1 in the pH exerts a marked effect while with stable milk the effect is not so great.

During the storage of sweetened condensed milk at 37° C. (98.6° F.) there is at first a slight decrease in pH and then a gradual rise of about 0.2 pH after which the reaction remains fairly constant during the aging period regardless of whether the milk thickens slowly or rapidly.

During the spring of the year the unstable milk may be stabilized by adding 60–125 grams (approximately 2–4 oz.) of sodium bicarbonate per 1000 pounds of raw milk. The sodium bicarbonate is more effective when added to the raw milk than when added to the finished product.

The increase in acidity due to forewarming cannot be considered an important factor.

Changes in electrical conductivity cannot be correlated with the stability of the milk toward age thickening.

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IRRADIATED EVAPORATED MILK: THE TRANSMISSION AND ANTIRACHITIC ACTIVATION OF EVAPORATED MILK FILMS BY ULTRA-VIOLET RADIATIONS

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National Carbon Company, Inc., Cleveland, Ohio

Numerous data (1–5) have shown the interrelationship between the antirachitic potency of irradiated milk and such factors as the intensity of the incident radiation, time of exposure and character of the milk film. These data have been concerned with natural fluid milk. No data have been available showing analogous interrelationships applicable to evaporated milk. The direct irradiation of evaporated milk presents certain conditions which preclude the assumption that the same or equivalent results will be obtained from the same treatment as applied to fluid milk. It has been shown that ultra-violet radiations within the antirachitic range are absorbed to a large extent by a fluid milk film 0.02 mm. thick; also, various constituents of milk absorb ultra-violet rays to a substantial degree, even in very low concentration (1). In the study of conditions required for efficient and effective activation of fluid milk, it was determined, that notwithstanding the low penetrating power of the antirachitic rays fluid milk could be activated to a substantial degree by appropriate correlation of intensity of the radiations and the character of the milk film as affected by film capacity, thickness, and speed of travel (3) (4).

The irradiation of evaporated milk as such, with its inherent solids content, wide range of viscosity at variable temperatures, homogenization and pre-heating temperatures, all of which are known to alter its physical properties, obviously, will not permit the direct application of the data from correlated studies with fluid milk. In the absence of specific information applicable to evaporated milk, studies similar to those previously carried out with fluid milk were undertaken, employing similar methods, and taking into consideration the inherent physical differences between the two products.

These experiments were designed to determine the following: the difference in degree of activation imparted to milk irradiated in fluid form and that irradiated after evaporation; the effect of irradiating evaporated milk before and after homogenization; the effect of irradiating at different film thicknesses; the effect of irradiating evaporated milk reconstituted to the same solids content as the original fluid milk; to determine the ultra-violet ray transmitting properties of evaporated milk as compared with those of

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fluid milk and as influenced by temperature, homogenization, and the preheating of fluid milk. A further objective of the experiments was to determine the degree of activation imparted to evaporated milk by three types of commercial equipment operated under known conditions and to compare the results with those obtained from the same equipment irradiating fluid milk.

EXPERIMENTAL

The experimental plan involved the use of evaporated milk as prepared and normally handled under routine conditions of production. A fully equipped evaporating plant was selected within a short distance from the Research Laboratories, thus permitting quick transportation of the unsterilized products to the laboratory where precision irradiation experiments, spectroradiometric data and other determinations could be made. The facilities also permitted a direct comparison of results obtained from the controlled studies in the laboratory with those obtained in the factory from the different types of commercial equipment. The work was done in the months of November, February and March. The several hundred different samples obtained during the study were canned in the regulation 14½ ounce can and subjected to the usual sterilizing process before running the bioassays. In order to eliminate uncontrollable variations insofar as practicable, nearly all tests were repeated three times with three different days' production.

The methods previously employed (1) for the study of the transmitting properties and activation of fluid milk films were used for the laboratory irradiation and spectroradiometric studies. The transmitting properties of the milk films were determined with the spectroradiometer mounted as described in a previous report (1). The carbon arc lamp burning "C" type electrodes at 50 volts and 60 amperes was mounted 43 cm. from the flowing film which for these experiments was maintained at a width of 10 cm. Uniformity of film flow rate was maintained by appropriate means for providing constant level of milk in the supply reservoir. Uniform film flow in the various commercial apparatus was maintained with the usual accessories supplied with each type apparatus and further checked by weighing the milk delivered from the apparatus at frequent intervals during treatment. The uniformity and intensity of the radiation emitted by the carbon arcs employed in the commercial apparatus was determined and continually recorded by the Westinghouse ultra-violet ray meter (5); uniform intensity of radiation during the particular test runs was maintained on the basis of the meter record irrespective of the voltage and amperage required to furnish the predetermined intensity of radiation desired. Total solids and fat content were determined on all lots of fluid and evaporated milk required for the experiments.

The bio-assays were made with the sterilized products reconstituted to the same solids content as the original milk. The usual assay procedure was employed wherein the groups of properly prepared rachitic animals receiving the Steenbock rachitogenic diet 2965 (6) were given 4 cc. of the test milk daily for a period of 10 days following a 21 day period on the rickets producing diet unsupplemented. The average degree of calcification from all the animals of the group receiving the same test milk was taken as the criterion of the relative vitamin D potency of the sample.

Record of significant physical and biological data are contained in the accompanying tabulations and graphs. In order to reduce extensive tabular material as much as possible, the average results of complete and independent runs are shown with indication of the maximum variation obtained from the individual experiments.

Table 1 shows comparable data from the irradiation of fluid milk and evaporated milk. In all instances the potency of the product irradiated as fluid milk is higher than that irradiated after evaporation. The magnitude of the greater potency of the fluid irradiated product is dependent upon the intensity of the incident radiation, the time of exposure and thickness of the milk film. Chart I shows the typical ultra-violet transmitting properties of films of fluid, and homogenized evaporated milk of known thickness and comparable film capacity, each determined at a temperature of 85° F. It will be noted that there is a relatively greater penetration of wave lengths below

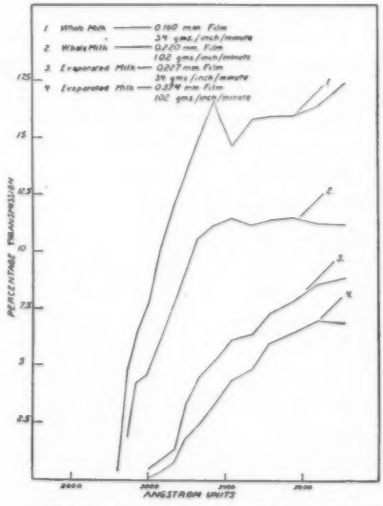
1. Whole Milk —— 0.160 mm. Film
3% gms./inch/minute
2. Whole Milk —— 0.260 mm. Film
1.02 gms/inch/minute
3. Evaporated Milk — 0.207 mm. Film
3% gms/inch/minute
4. Evaporated Milk — 0.374 mm. Film
1.02 gms/inch/minute
PERCENTAGE TRANSMISSION
ANGSTROM UNITS

CHART I. Transmission of ultra-violet radiations by films of fluid whole milk and evaporated milk.

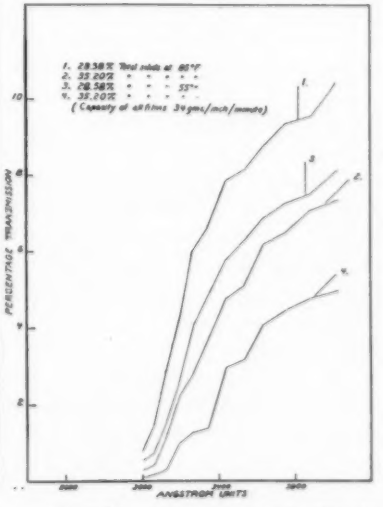
1. 28.38% Total solids at 85°F
2. 35.20% " " " " "
3. 28.58% " " " 55°"
4. 35.20% " " " "
(Capacity of all films 3% gms./inch/minute)
PERCENTAGE TRANSMISSION
ANGSTROM UNITS

CHART II. Transmission of ultra-violet radiations by films of evaporated milk of different percentage total solids.

TABLE 1

The antirachitic potency of fluid and evaporated milk irradiated under comparable and controlled conditions with laboratory and commercial equipment

("C" carbons used in all cases except with Type V equipment in which "U" were used)

IRRADIATING EQUIPMENT	MATERIAL IRRADIATED	AVERAGE % SOLIDS	AVERAGE RATE PER HOUR	FILM CAPACITY PER INCH PER MIN.	FILM THICKNESS	EXPOSURE PERIOD	ULTRA-VIOLET METER RECORD AT SHORTEST DISTANCE FROM ARC TO MILK	RICKETS HEALING (AVE. LINE TEST)
(1)			(lbs.)	(gms.)	(mm.)	(secs.)	(in.)	(rate per min.)	(+)
Laboratory	Fluid Milk	12.08 ± .12		34.02 ± .16	0.14 ± .02	1.9 ± .06	17	13 ± 0.6	3.13 ± 0.46
"	Evap. Milk, not homo.	28.50 ± .30		34.02 ± .16	0.24 ± .02	4.3 ± .10	17	13 ± 0.6	2.50 ± 0.27
"	Evap. Milk, homo	28.50 ± .30		34.02 ± .16	0.25 ± .02	4.6 ± .10	17	13 ± 0.6	2.65 ± 0.28
"	Fluid Milk	12.08 ± .12		102.06 ± .60	0.23 ± .03	1.3 ± .06	17	13 ± 0.6	2.00 ± 0.3
"	Evap. Milk, not homo.	28.50 ± .30		102.06 ± .60	0.35 ± .08	2.6 ± .03	17	13 ± 0.6	1.52 ± 0.36
"	Evap. Milk, homo	28.50 ± .30		102.06 ± .60	0.39 ± .06	2.7 ± .07	17	13 ± 0.6	1.47 ± 0.28
Com'l Type I	Fluid Milk	11.85 ± .10	2475	222.6 ± 3.7	0.40 ± .04	8.0 ± .80	24	6.6 ± 0.4	1.83 ± 0.18
" "	Evap. Milk, not homo.	28.19 ± .92	2501	223.4 ± 5.2		12*	24	6.5 ± 0.4	1.34 ± 0.36
" "	Evap. Milk, homo.	27.51 ± .40	2527	224.7 ± 4.3		24*	24	6.5 ± 0.4	1.75 ± 0.15
Com'l Type II	Fluid Milk	11.93 ± .13	4526	244.0 ± 3.4	0.29 ± .01	2.4 ± .06	22	7.7 ± 0.4	1.80 ± 0.30
" "	Evap. Milk, homo.	30.23 ± .24	4469	241.5 ± 2.2		4.2*	22	7.7 ± 0.4	1.10 ± 0.40
Com'l Type V	Fluid Milk	12.07 ± .00	4008	1018.0	0.17**	0.05*	4.5	(***)	1.75 ± 0.25
" "	Evap. Milk, homo.	27.87 ± .43	4251	1080.0		0.05*	4.5	(***)	1.45 ± 0.35

(*) Estimated Exposure Period.

(**) Approximate film thickness as stated by manufacturers.

(***) Relative intensity of the radiation transmitted through the milk film showed 2.9 ± 0.15 discharges per minute at a distance of 24 inches from the arc in the case of fluid milk; and 1.42 ± 0.09 per minute at the same distance for evaporated milk.

3000 Å in fluid milk than in the evaporated product. This difference is primarily due to the difference in solids content and film thickness, although data which will be presented later in this report show that the lower transmitting properties of evaporated milk is not due solely to these two conditions.

Variations in the solids content of different lots of evaporated milk may affect the ultra-violet transmitting properties. This is illustrated by the graphs in Chart II. The percentage transmission at 3000 Å for evaporated milks of 28.58 per cent solids and 35.20 per cent solids, each having the same film capacity and determined at 55 and 85 F., is in each case less than 1 per cent, and the variation caused by the difference in solids content is less than $\frac{1}{2}$ per cent. Below 3000 Å the percentage transmission was practically immeasurable with the apparatus used. In order to determine whether the apparent slight difference in transmitting properties within the antirachitic range had a practical bearing on the antirachitic potency, the two evaporated milks were irradiated with the laboratory apparatus under twenty different conditions wherein temperatures, film thickness, and film capacity were the variables and the intensity of the incident radiation constant. The results were not consistent in showing any significant difference in degree of potency attributable to difference in solids content. In four comparable cases there was no difference whatsoever in the potency of the two products; in five cases the higher solids product showed a slightly higher average potency; whereas; in eleven comparable cases the product with lower solids showed a slightly higher potency. The results as a whole cannot be considered as showing any significant difference in potency resulting from irradiating evaporated milk with solids content varying from 28 to 35 per cent.

Since temperature and homogenization are known to affect the viscosity of evaporated milk and consequently film flow characteristics, a series of irradiation experiments and transmission measurements were made with the laboratory apparatus; the factors mentioned being the variables correlated with the antirachitic potency while the incident radiation remained constant. The results are shown in Table 2 and Charts III and IV. An examination of the data shows that there is no consistent and significant difference in the potency of evaporated milk irradiated before or after homogenization; neither is there a consistent or distinctive difference in potency attributable to temperature of irradiation throughout the range from 55 to 165° F. Each of the variable factors concerned in this study contribute to variations in film thickness and period of exposure. The product of the value for film thickness multiplied by the time of exposure is higher for the low film capacity rate at all temperatures except 55 and 165° F., than the product figures for the higher film capacity rate; the potency of the milk irradiated at the lower rate is likewise uniformly and significantly higher than at the higher rate. This distinctive difference in potency is probably the most conclusive and

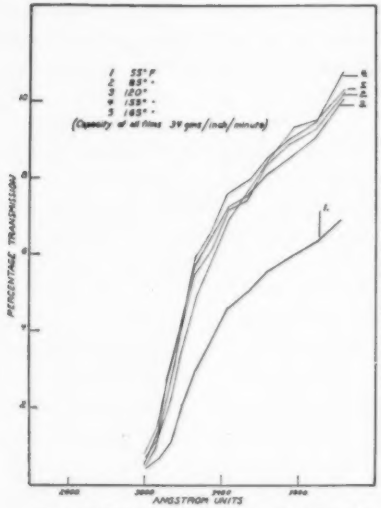

CHART III. Transmission of ultra-violet radiation by films of non-homogenized evaporated milk at different temperatures.

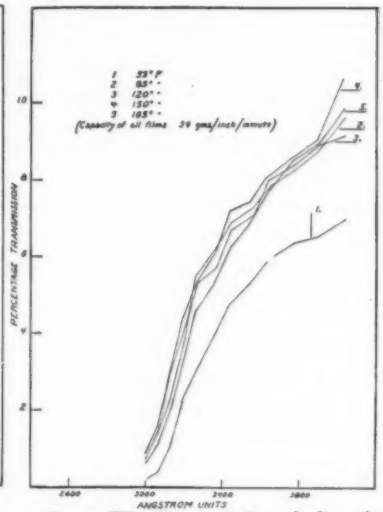

CHART IV. Transmission of ultra-violet radiations by films of homogenized evaporated milk at different temperatures.

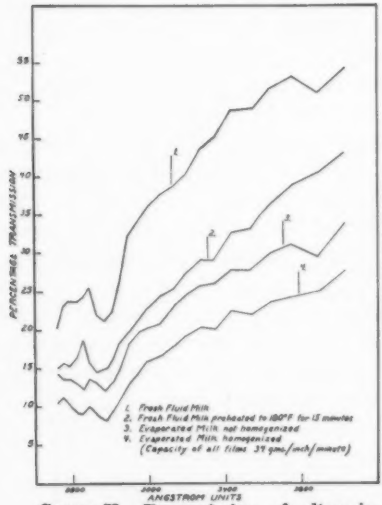
1. Fresh Fluid Milk
2. Fresh Fluid Milk preheated to 180°F for 15 minutes
3. Evaporated Milk not homogenized
4. Evaporated Milk homogenized
(Capacity of all films 34 gms/inch/minute)
PERCENTAGE TRANSMISSION
ANGSTROM UNITS

CHART V. Transmission of ultra-violet radiations at 55° F. by films of milk diluted to 3% solids concentration.

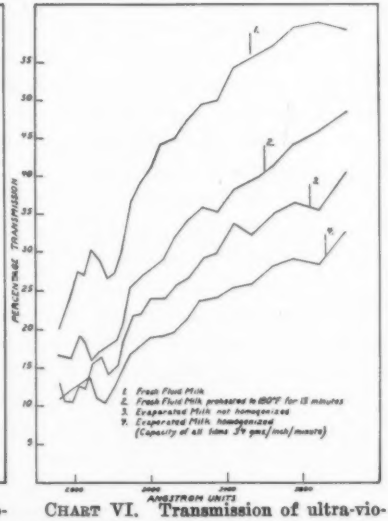
1. Fresh Fluid Milk
2. Fresh Fluid Milk preheated to 180°F for 15 minutes
3. Evaporated Milk not homogenized
4. Evaporated Milk homogenized
(Capacity of all films 34 gms/inch/minute)
PERCENTAGE TRANSMISSION
ANGSTROM UNITS

CHART VI. Transmission of ultra-violet radiations at 85° F. by films of milk diluted to 3% solids concentration.

TABLE 2

The antirachitic potency of evaporated milk irradiated as such as affected by temperature and film characteristics

(Average solids as irradiated 28.78 ± 0.22%; "C" carbon, 17 inches from arc to milk film; vertical distance of film travel, 16 inches; ultra-violet meter rate, 13 ± 0.6 per min.)

MATERIAL IRRADIATED	TEMP.	VISCOSITY (*) (SECS. PER 100 GMS.)	FILM CAPACITY PER IN. PER MIN.	FILM THICKNESS	EXPOSURE PERIOD	RICKETS HEALING (AVE. LINE TEST)
			(*gms.*)	(*mm.*)	(*secs.*)	(+)
Evap. Milk, not homo.	55	43.6	34.02 ± .16	.260	4.47	2.62 ± 0.18
" " homo.	55	46.3	34.02 ± .16	.280	4.85	2.62 ± 0.28
" " not homo.	55	43.6	102.06 ± .60	.468	2.92	1.44 ± 0.16
" " homo.	55	46.3	102.06 ± .60	.473	2.95	1.45 ± 0.16
Evap. Milk, not homo.	85	34.1	34.02 ± .16	.231	4.32	2.50 ± 0.36
" " homo.	85	34.7	34.02 ± .16	.227	4.63	2.25 ± 0.05
" " not homo.	85	34.1	102.06 ± .60	.353	2.20	1.55 ± 0.35
" " homo.	85	34.7	102.60 ± .60	.374	2.60	1.40 ± 0.40
Evap. Milk, not homo.	120	30.6	34.02 ± .16	.225	4.21	3.06 ± 0.60
" " homo.	120	31.6	34.02 ± .16	.215	4.03	2.37 ± 0.17
" " not homo.	120	30.6	102.06 ± .60	.288	1.80	1.56 ± 0.34
" " homo.	120	31.6	102.06 ± .60	.299	1.87	1.62 ± 0.12
Evap. Milk, not homo.	150	27.0	34.02 ± .16	.196	3.63	2.87 ± 0.23
" " homo.	150	33.6	34.02 ± .16	.195	3.65	2.20 ± 0.30
" " not homo.	150	27.0	102.06 ± .60	.272	1.70	1.50 ± 0.10
" " homo.	150	33.6	102.06 ± .60	.283	1.77	1.62 ± 0.09
Evap. Milk, not homo.	165	29.7	34.02 ± .16	.176	3.30	2.87 ± 0.13
" " homo.	165	40.2	34.02 ± .16	.224	4.20	2.50 ± 0.50
" " not homo.	165	29.7	102.06 ± .60	.304	1.90	1.12 ± 0.02
" " homo.	165	40.2	102.06 ± .60	.307	1.92	1.37 ± 0.17

(*) Saybolt Viscoscimeter used.

characteristic evidence shown by the data in Table 2. However, the data as a whole seem to be equally conclusive in showing that the antirachitic response of evaporated milk irradiated as such is not solely determined by the power factor involving intensity of radiation per unit amount of milk and period of exposure. Evidence of similar character from fluid milk has been reported heretofore (3) (7).

The direct relationship between viscosity and film thickness seems to be most significant throughout the temperature range from 55 to 150° F. or thereabouts, and the greatest apparent effect of viscosity on film thickness appears to lie between the temperatures of 55 and 85° F. Similar relationships are also shown by fluid milk as will be noted in Table 3. The transmission of ultra-violet rays through the evaporated milk films at different

TABLE 3

The effect of temperature on the viscosity and film thickness of fluid whole milk

TEMPERATURE	VISCOSITY* (SECS. PER 100 GMS.)	FILM CAPACITY PER IN. PER MIN.	FILM THICKNESS	EXPOSURE PERIOD DURING 16-INCH VERTICAL TRAVEL
		(*gms.*)	(*mm.*)	(*secs.*)
55	26.4	34.02	.183	3.43
55	26.4	102.06	.304	1.90
85	23.7	34.02	.164	3.07
85	23.7	102.06	.218	1.36
120	22.9	34.02	.150	2.80
120	22.9	102.06	.179	1.22
150	22.3	34.02	.136	2.55
150	22.3	102.06	.192	1.20
165	23.1	34.02	.139	2.60
165	23.1	102.06	.192	1.20

* Saybolt Viscosimeter used.

temperatures (Charts III and IV) shows clear evidence of a critical temperature between 55 and 85° F. According to these curves the transmission of the shorter ultra-violet rays at about 3000 Å or below does not appear to be substantially different throughout the temperature range of 55 to 165° F. However, there is a marked difference in transmission of the longer ultra-violet at temperatures of 55° F. and 85° F., but practically no difference throughout the range from 85 to 165° F. These results as a whole cannot be entirely explained as due to differences in viscosity and film thickness.

It has been previously shown (8) that milk contains a protein fraction which has a critical agglomeration temperature at about 73° F. The agglomerate manifested above this temperature could be redispersed to a water clear solution simply by lowering the temperature. Agglomeration and redispersion was found to be reversible and a function of temperature providing the colloidal suspension had not been previously heated at too

high a temperature, or held too long at lower temperatures. A water clear suspension of this material in 0.04% concentration absorbed appreciable ultra-violet radiation in the antirachitic range and the absorption was further increased by agglomeration of the molecules. It is suggested that the physical properties of this material are in some manner concerned in determining the character of the milk films involved in the present study. In order to determine if these previous observations are pertinent in the principles and practices prevailing in the commercial irradiation of evaporated milk, the transmitting properties of fluid and evaporated milk as affected by heat treatment and the usual processing steps, were determined.

Since a measurable degree of transmission within the ultra-violet range was desired in order to accentuate differences, all test samples were diluted with water to 3 per cent total solids; the same film capacity of all samples of diluted milk was used for the spectroradiometric measurements. Data were obtained from normal fluid milk not previously heated, the same milk heated to 180° F. and held for 15 minutes, and from parallel samples of homogenized and non-homogenized evaporated milk prior to final sterilization. The results are shown in Charts V and VI from which the following differences are obvious.

The percentage transmission of all wave lengths measured, including those in the antirachitic range is distinctively greater for the fluid milk not previously heated than it is for the pre-heated milk, or the evaporated milk irrespective of the temperature at which the measurements were made. It appears that the progression of steps in the processing of evaporated milk, namely, the initial pre-heating, concentration, and homogenization, each contributed additively to change its physical character in a manner which tends to decrease the ultra-violet transmitting properties. This progressive decrease is especially pronounced in the ultra-violet range above 2950 Å, although the same relative effect is also shown in the antirachitic region below 2950 Å but to a lesser degree.

This type of study involving measurement of milk films of known characteristics may prove to be a useful method for determining the physical character of milk, particularly as affected by physical treatment. The difference in the transmitting properties of the various milk appears to be in harmony with expectations based upon observations from previous study of the colloidal protein constituent of milk already discussed. It would seem quite apparent that the screening effect of agglomerated colloidal matter or increased density of suspended particles would tend to decrease the efficiency of the incident irradiation.

It appears that there are two reasons which account for the difference in potency of fluid milk and evaporated milk irradiated as such. The first, and undoubtedly the most significant, is the greater film thickness of the evaporated product. As shown in the controlled experiments with labora-

tory apparatus, this can be compensated for in part by the exposure of thinner films subjected to the radiations for longer periods of time. The balanced relationship between film capacity, film thickness, time of exposure and appropriate intensity of radiation necessary for the treatment of evaporated milk in order to impart a potency as high as is obtained in fluid milk presents practical operating and engineering problems which are not yet overcome in the available commercial equipment.

The second reason for the lower potency of evaporated milk treated under conditions paralleling those used for fluid milk, is the inherent and accumulative change in the physical character of the product caused by heat, concentration and homogenization. The degree to which these inherent conditions directly affect antirachitic potency, aside from contributing to increased thickness and density of the film, is illustrated by the following: Parallel samples of fluid and evaporated milk, homogenized and non-homogenized, were irradiated with the laboratory apparatus under identical conditions after reconstituting the evaporated product to the same solids content as contained in the normal fluid milk. The average degree of calcification (average line test) from 4 cc. of the irradiated fluid milk was 3.13+; for the reconstituted non-homogenized evaporated milk, 3.04+; and for the homogenized product 2.80+. The average variation between individual samples within each of the specified groups was 0.16+. These results were obtained under strictly comparable conditions wherein high intensity radiations were employed. The films were substantially 0.10–0.12 mm. thick and the exposure period was approximately 1 second. Under these conditions wherein all factors were synchronized to give a maximum degree of potency in an efficient manner, the difference in the vitamin D content attributable solely to the difference in physical character of the milk constituents is not great, but nevertheless measurably lower from the homogenized evaporated product than from the fluid milk.

Table 4 shows comparable data from an extended series of irradiation experiments with commercial equipment (Type II) wherein factory methods prevailed in the treatment of evaporated milk. The experiments were fully controlled with regard to known and predetermined film capacity and intensity and character of the incident radiation. The data readily reveals that there is a certain degree of correlation between film capacity, or rate of operation in terms of pounds per hour, and the antirachitic potency, and also between intensity of the incident radiation and potency. However, the highest potency obtained at the lowest rate of operation and highest intensity is substantially less than obtained during the irradiation of fluid milk with the equipment operated at similar capacities and with comparable intensity of radiation (Table I). Furthermore, it will be noted that the potency of all samples is substantially less than that obtained in the precision control experiments with laboratory apparatus operated at the lower capacity rate.

TABLE 4

The antirachitic potency of evaporated milk irradiated as such as affected by type of carbon and capacity of operation of commercial irradiating equipment type II

(Average Percent Solids in Evaporated Milk as Irradiated 28.11 ± 0.08; temperature during irradiation 125° F. ± 10°)

SOURCE OF RADIATION	AVE. RATE PER HOUR	FILM CAPACITY PER IN. PER MIN.	EXPOSURE PERIOD	ULTRA-VIOLET METER RECORD AT SHORTEST DISTANCE FROM ARC TO MILK		RICKETS HEALING (AVE. LINE TEST)
	(*lbs.*)	(*gms.*)	(*secs.*)	(*ins.*)	(*rate per min.*)	(+)
"C" carbon	6200	334.3 ± 3.2	3.8 (*)	22	7.6 ± 0.3	0.97 ± 0.37
"U" carbon	"	"	"	"	12.9 ± 1.3	1.13 ± 0.07
"C" HI carbon	"	"	"	"	9.8 ± 0.9	1.10
"C" carbon	5730	309.9 ± 2.3	4.0 (*)	22	7.8 ± 0.2	0.90 ± 0.20
"U" carbon	"	"	"	"	12.9 ± 1.2	1.23 ± 0.27
"C" carbon	5080	268.0 ± 3.4	4.2 (*)	22	7.8 ± 0.2	0.93 ± 0.27
"U" carbon	"	"	"	"	12.9 ± 1.2	1.26 ± 0.26
"C" carbon	4280	231.0 ± 1.0	5.0 (*)	22	7.8 ± 0.3	1.17 ± 0.06
"U" carbon	"	"	"	"	12.8 ± 0.9	1.47 ± 0.07
"C" carbon	3400	182.6 ± 0.0	5.6 (*)	22	7.7 ± 0.3	1.36 ± 0.13
"U" carbon	"	"	"	"	12.8 ± 0.9	1.50 ± 0.10

(*) Estimated Exposure Period.

The data presented in this report were obtained for the purpose of illustrating the concrete effect of various factors and interrelationship of factors which contribute to the degree of antirachitic potency obtained during the irradiation of milk, more particularly, evaporated milk. In comparing the results from the irradiation of evaporated milk as such with those from the irradiation of fluid milk, the same basic relationships are involved. However, the irradiation of evaporated milk presents certain inherent problems accentuated to a greater degree than is applicable in the irradiation of fluid milk. The differences in the inherent character of the two products are such that a lower degree of potency in the evaporated product inevitably results irrespective of the degree of control of factors known to be significant. The operation, design, and engineering features now prevalent in commercial irradiation equipment does not permit as high a degree of antirachitic potency in the evaporated product as it is possible to obtain by the same or equivalent operation during the treatment of fluid milk. If irradiated evaporated milk and irradiated fluid milk are to have the same antirachitic potency as determined by current methods of assay, the only way of accomplishing this result with present equipment is to irradiate the fluid product before concentration, otherwise, the two products, even though both are competently treated, must be classified and recognized as having different assay values.

SUMMARY

1. The irradiation of evaporated milk as such does not result in as high a degree of antirachitic potency as the irradiation of fluid milk when films of the same capacity are subjected to the same intensity and quality of ultra-violet radiation.

2. Films of evaporated milk of the same capacity are thicker and more dense than those of fluid milk with the same capacity. The depth of penetration of the ultra-violet rays, or transmitting properties of evaporated milk films is consequently less than that of fluid milk films.

3. The degree of antirachitic activation imparted to evaporated milk is not significantly different from the homogenized and non-homogenized product; nor is it significantly affected by irradiating at temperatures varying from 55 to 165° F.

4. The ultra-violet transmitting property of milk is progressively decreased by pre-heating to 180° F., by concentration, and by homogenization. This decrease is caused by physical changes in the inherent milk constituents, and is independent of the density and thickness of the milk films.

5. Greater antirachitic potency of evaporated milk irradiated as such may be brought about by exposure of thinner films for longer periods of time, or by increasing the intensity of the incident radiation. The potency obtained by such means is not equal to the potency obtained by the irradiation of fluid milk films treated under comparable conditions.

The authors wish to record appreciation of the cooperation extended by the Creamery Package Manufacturing Company and the Cherry-Burrell Corporation for the loaning of equipment and for providing certain facilities necessary for conducting particular phases of the work reported herein.

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A STUDY OF VARIATIONS IN THE LACTOSE CONTENT OF MILK*

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It seems to have been taken for granted that lactose is the least variable of the major constituents of milk. A review of the literature, however, reveals a lack of experimental data in support of this idea and also a need for more work on this phase before other important experimental work on the secretion of lactose can be launched.

HISTORICAL

That there are marked variations in the lactose content of milk was reported as early as 1891 by Van Slyke (15). Eckles and Shaw (5) among others have furnished abundant evidence in support of this fact. The literature reports on the variations in blood sugar in lactating animals are not so conclusive. Awdejewa and co-workers (2) report marked daily variations in blood sugar, while Richter (10) reports but slight variations. Schuenert and Pelchrigin (12), Hayden and Fisk (6), Moussu and Moussu (9), and Awdejewa and co-workers (2) have been unable to find any marked difference between the blood sugar levels in lactating and non-lactating cows. In marked contrast Widmark and Carlens (16), Auger (1), Schwarg, Mezler, Andelburg (14), Schlothauer (14), Hewitt (7), Hodgson, Riddell and Hughes (8) and Blackwood and Sterling (3) report lower blood sugar for lactating than non-lactating cows.

Attempts to influence the blood sugar level by feeding sugars failed to produce results—Carlens and Krestownokoff (4), Richter (10), Scheicher (11) and Hodgson, Riddell and Hughes (8). The latter, however, report that when 6 to 8 pounds of sugar were introduced into the stomach by means of a stomach tube a marked hyperglucemia resulted.

The Problem

Inasmuch as the literature failed to reveal any definite information as to the relationship of blood sugar and lactose, or to hourly variations of these constituents, a series of experiments was projected to determine whether the daily and hourly variations occurring under normal herd conditions were great enough to modify our experimental results.

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* The data in this paper are taken mainly from a thesis presented by W. R. Brown in partial fulfillment for the Ph.D. degree and published with the approval of the Director as Paper No. 1380.

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Experimental

The animals used in all the experimental work were purebreds, and unless otherwise noted were all on the regular herd ration, with water *ad-lib*.

Collection of Samples

The milk samples used in the study of the morning and evening milks were obtained from the bucket immediately after the milker had finished stripping the gland. The samples were collected in half-pint bottles, to which a few drops of chloroform had been added. They were then stored in a refrigerated room at 6° C. until analysed. The period between sampling and preparation for analysis was about twelve hours. The samples used for the study of the hourly variations were obtained by stripping the right half gland at each sampling.

The blood samples were obtained from the jugular vein, using sodium citrate as an anticoagulant. Filtrates were prepared according to the Folin-Wu method.

Analysis of Samples

The lactose determination of the milk was carried out according to the colorimetric picric acid method of Bierman and Doan.[3] The standard solution was freshly prepared each week and consisted of one per cent pure lactose dissolved in picric acid solution saturated at 20° C.

Duplicate, five cubic centimeter, samples of the blood filtrate were taken for the glucose determinations, which were carried out by the micro method of Shaffer-Hartmann.

Experiment 1

Samples of the morning and evening milk were collected from Jersey cows 143, 160, 163 and 167, and from Guernsey cows 538, 544, 550 and 551 and analysed for lactose. Cows 160, 163, 544, 550 and 551 were used for one day, cows 167 and 538 were used for two days, and cow 143 was used for five days.

Experiment 2

Twelve consecutive hourly samples of milk were collected from Jersey cows 143, 160, 163 and 167, and from Guernsey cows 538, 544, 550 and 551 and analysed for lactose. From cows 160, 163, 167, 538, 550 and 551 simultaneous collections of blood were made and analysed for glucose. In the case of cows 160, 163, 538 and 551, the hourly milk samples were measured, in order that the total lactose secreted might be determined.

[3] JOURNAL OF DAIRY SCIENCE, p. 381, 1924.

Results

Experiment 1

Table 1 shows the variations in lactose between samples of milk obtained from the pail of the milker at the time of the regular morning and evening

TABLE 1

Comparison of the lactose content of morning and evening milk

COW NO.	BREED	PER CENT LACTOSE	
		A. M. Milk	P. M. Milk
143	Jersey	4.85	4.40
"	"	4.43	4.68
"	"	5.09	5.30
"	"	4.85	4.86
"	"	4.48	4.72
160	"	4.70	4.65
163	"	4.71	3.97
167	"	4.99	4.68
"	"	4.64	4.32
538	Guernsey	5.02	4.75
"	"	5.41	5.47
544	"	4.76	5.23
550	"	4.40	4.36
551	"	5.22	5.07
	Average	4.82	4.75

milkings. In all eight cows are included, and, as they were on the regular herd ration, the results recorded are what may be expected to hold for normal cows under general herd conditions.

Experiment 2

Table 2 shows the amount of lactose found in samples of milk collected at hourly intervals, from 6 cows, between the regular morning and evening milkings and for one cow between evening and morning milkings. Table 3 shows the blood sugar found in hourly samples of blood, taken almost simultaneously with the milk samples from 6 of the cows, and Table 4 shows the amount of milk obtained at the hourly milking from 4 of them.

Figures 1, 2, 3 and 4 illustrate graphically the results obtained with cows 160, 153, 538 and 551.

DISCUSSION OF RESULTS

Table 1 shows that if cows are milked at regular intervals, twice daily, the deviations between the sugar content of the morning and evening milk samples are reasonably small. Table 2, on the other hand, indicates that if hourly samples of milk are taken the lactose is subject to wide variation. The blood samples recorded in Table 3, which were collected at the same

TABLE 2

Comparison of the lactose content in hourly samples of milk

COW NO.	BREED	LACTOSE IN MILK											
		Time											
		A. M.							P. M.				
		6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00
		%	%	%	%	%	%	%	%	%	%	%	%
160	Jersey	4.70	4.65	4.34	5.03	5.04	4.49	4.67	4.65	4.64	4.65	4.38	4.40
153	"	4.71	3.03	2.85	3.67	3.92	3.63	4.05	3.59	4.15	4.11	4.04	3.95
167	"	4.99	4.48	4.27	4.27	4.25	4.17	4.35	4.49	4.65	4.75	4.68	4.68
538	Guernsey	5.02	4.36	4.67	4.49	4.50	4.88	5.09	5.06	5.29	5.20	5.21	4.75
550	"	4.40	4.18	4.21	3.95	3.95	3.88	3.95	4.00	4.21	4.38	4.66	4.36
551	"	5.22	4.83	4.73	5.09	4.68	4.87	5.04	5.42	4.83	5.36	5.20	5.22
		P. M.							A. M.				
143	Jersey	4.70	4.35	3.65	4.45	4.45	4.40	4.15	4.40	4.35	4.55	.....	4.77

TABLE 3

Comparison of the blood sugar in hourly samples

COW NO.	BREED	GLUCOSE IN BLOOD											
		Time											
		A. M.							P. M.				
		6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00
		%	%	%	%	%	%	%	%	%	%	%	%
160	Jersey	.025	.037	.035	.027	.028	.028	.028	.030	.028	.024	.025	.020
153	"	.028	.024	.033	.027	.018	.021	.030	.025	.018	.022	.021	.025
167	"	.038	.031	.035	.035	.038	.037	.041	.045	.054	.049	.038	.044
538	Guernsey	.038	.045	.029	.035	.037	.040	.040	.043	.032	.040	.034	.037
550	"	.035	.032	.032	.042	.041	.039	.034	.034	.038	.038	.038	.035
551	"	.037	.038	.033	.037	.028	.040	.029	.034	.023	.027	.025	.020

TABLE 4

Cubic centimeters of milk obtained at hourly milkings

COW NO.	BREED	CC. OF MILK											
		Time											
		A. M.							P. M.				
		6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00
160	Jersey	.....	26	60	440	410	170	217	189	175	170	183	137
153	"	.....	26	27	42	59	137	72	95	145	96	103	142
538	Guernsey	.....	120	89	143	30	128	158	172	173	745	475	350
551	"	.....	118	59	126	32	35	205	370	1000	625	184	210

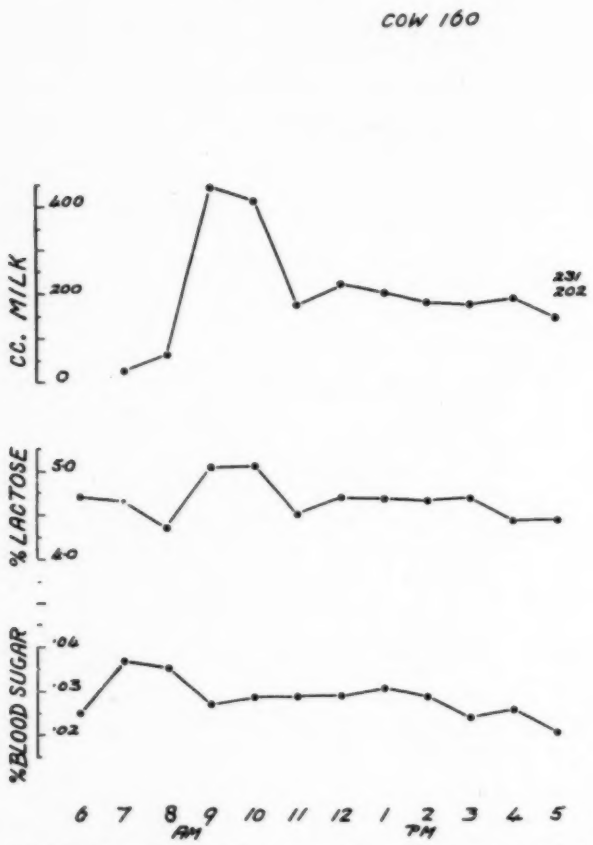

FIG. 1. Hourly fluctuations in blood sugar, CC. milk secreted, and lactose content of milk.

202 cc. hourly milk secreted for above 11-hour period.

231 cc. average hourly milk secreted for 10 days preceding experiment.

time as these hourly milk samples, likewise show marked fluctuations in the percentage of glucose present. The hourly variations found in the blood glucose suggested a reason for the wide lactose variations, so the correlation coefficients of these variables were determined.

The correlations between the milk lactose and the blood glucose, when the samples were collected almost simultaneously, are negative in five out of the six cases. The probabilities of these coefficients arising through random sampling from uncorrelated material are in all six cases too high to permit of the attachment of significance to the correlations. When the same data

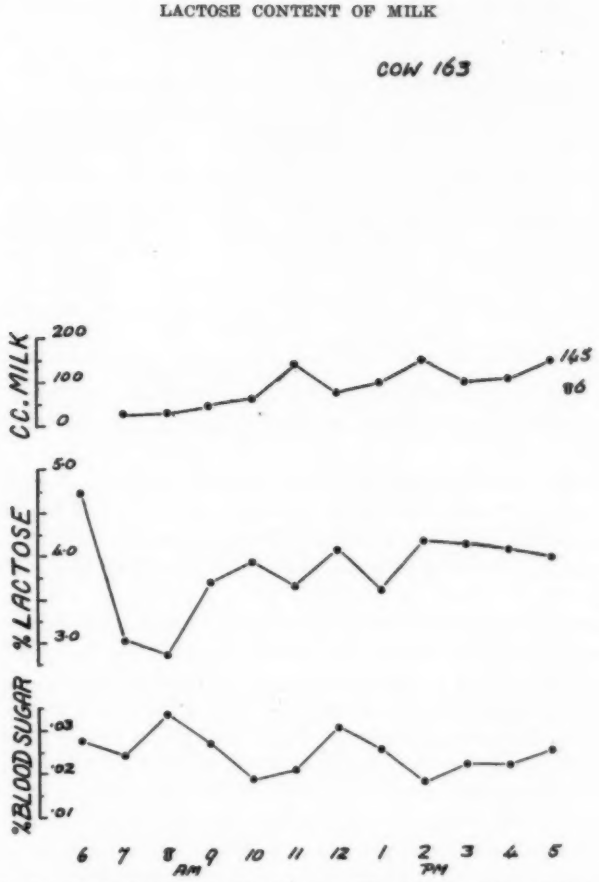

FIG. 2. Hourly fluctuations in blood sugar, CC. milk secreted, and lactose content of milk.

86 cc. hourly milk secreted for above 11-hour period.
145 cc. average hourly milk secreted for 10 days preceding experiment.

were used to correlate the blood sugar with the milk sugar of the collection one hour later, five of the six samples became more positive. However, only one of these is significantly positive, while one other coefficient (Cow 551) is significantly negative. The circumstance that five out of the six correlations became more positive appears of itself to be significant, as such would occur only once in sixty-four trials through random sampling only. This may indicate a tendency towards a definite association of the variables which is obscured by the extremely small size of the samples. These data are recorded in Table 5.

TABLE 5

The correlation between blood sugar and lactose

COW NO.	CORRELATION WHEN SAMPLES ARE COLLECTED ALMOST SIMULTANEOUSLY		CORRELATION WHEN BLOOD SAMPLES WERE COLLECTED ONE HOUR BEFORE MILK SAMPLES	
		P		*P*
153	$-.3256 \pm .258$	.30	$+.0530 \pm .301$	.88
160	$-.0001 \pm .289$	1.00	$+.1434 \pm .295$	.68
167	$+.4111 \pm .162$	.19	$+.8057 \pm .112$	.01
538	$-.1009 \pm .286$	.74	$+.3504 \pm .234$	.29
550	$-.1935 \pm .187$	.55	$-.0672 \pm .300$	.84
551	$-.1595 \pm .281$	.62	$-.6921 \pm .157$	.02

The failure to demonstrate a relationship between the blood and milk sugar is possibly due to several interfering factors, some of which will be considered.

The fairly constant lactose values obtained between twice-daily milk samples, and the wider variations obtained between samples collected at more frequent intervals agree with the results of Eckles and Shaw, but such hourly variations as have been found in the blood sugar have never before been reported.

One possible explanation as to the cause of these blood sugar fluctuations is that in the dairy cow, which is in reality an abnormal but highly specialized organism devoted to the special work of milk production (more than in any other animal), certain of the blood constituents are removed in large quantities by the mammary gland. In the case of the blood sugar it seems possible that it may be continually removed but not replenished from the liver until a certain low level is reached. This would result in a continuous series of waves, of whose duration we are ignorant, and it is possible that our hourly samples have been taken at different points on these waves.

It is thought that the explanation for the greater uniformity of the lactose in the twice-daily milkings is that although the blood sugar continually fluctuates, it probably does so around a slowly changing mean; consequently, while the percentage of lactose secreted by the gland is continually changing, the storing of the milk in the gland over a period of hours, before it is drawn, results in a mixing of all the milk secreted with the production of what is essentially an average or composite sample for the whole intermilking period. If this is actually the case the reason for the variations between the hourly samples becomes more apparent, because if the lactose is secreted against the blood sugar any slight variation in the latter will modify the lactose secreted so that, as the intergland mixing is considerably lessened, the milk obtained reflects the blood sugar variations to a greater extent.

Every milk sample, however, is probably modified by several factors. For instance it has been a common experience to find that the quantity of milk

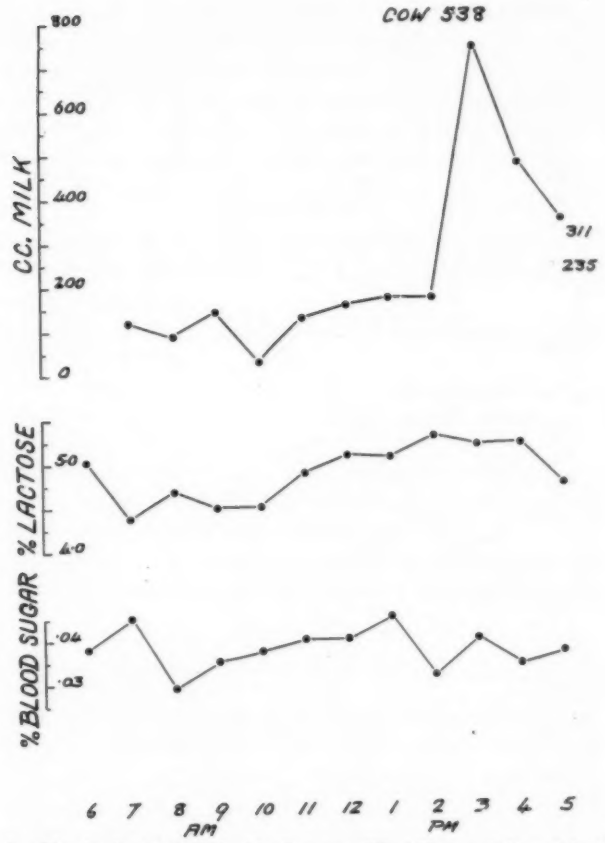

FIG. 3. Hourly fluctuations in blood sugar, CC. milk secreted, and lactose content of milk.

235 cc. hourly milk secreted for above 11-hour period.

311 cc. average hourly milk secreted for 10 days preceding experiment.

obtained at successive hourly milkings varies greatly. If, as is thought by most recent workers, the secretion of milk is a continuous and constant process, these varying quantities of milk can only mean an unequal liberation of milk into the teat ducts, and as much experimental evidence indicates, a storage of milk in the gland even though the latter has been carefully stripped. This stored milk, which may have been secreted against a different blood sugar, later drains into the ducts and mixes with that produced since the last milking. Likewise, some milk produced since the last milking will probably be unavailable at the next stripping. That the amount of milk

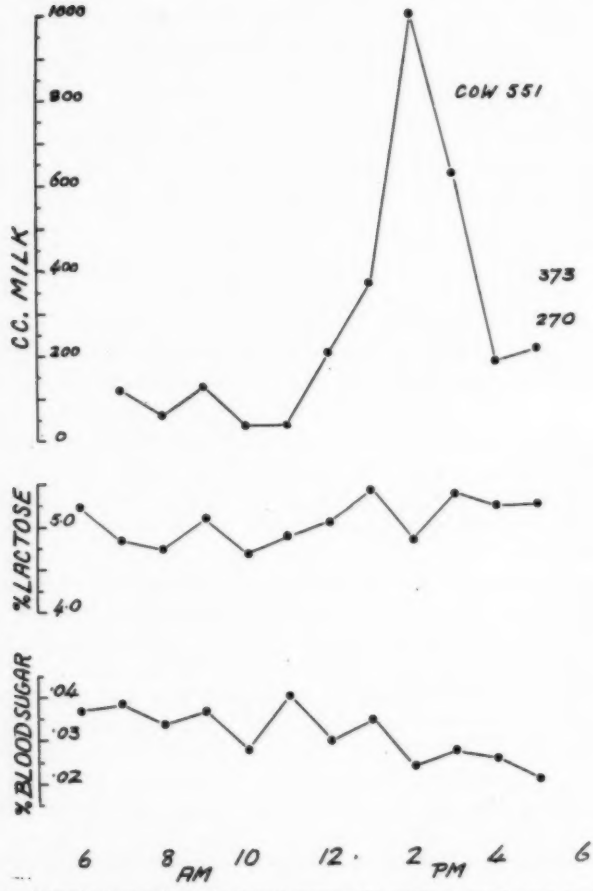

FIG. 4. Hourly fluctuations in blood sugar, CC. milk secreted, and lactose content of milk.

270 cc. hourly milk secreted for above 11-hour period.

373 cc. average hourly milk secreted for 10 days preceding experiment.

remaining after stripping varies in quantity renders the application of a constant correction for this factor impracticable.

CONCLUSIONS

Because of the complications outlined it appears that the satisfactory sampling of milk and blood for comparison studies is one of the most difficult problems confronting the investigator in this field. The results indicate that the old method of taking a blood sample just prior to the usual

milking period, and then the milk sample is not as satisfactory as when the gland is first stripped, a blood sample taken and then the milk sample collected, by stripping the gland one hour later.

It is fully realized that this method does not completely solve the problem of sampling the blood and milk for comparison studies, but it is thought to have a distinct advantage over the older and generally used one.

SUMMARY

1. A similarity was found between the lactose content of the morning and evening milk of individual animals, when the samples were taken at the regular milking periods.

2. The lactose content of the milk showed considerable variation between successive hourly samples.

3. Hourly variations were found in the blood sugar of milking cows.

4. Simultaneously collected samples of blood and milk show little or no positive correlation as to sugar content.

5. In general samples of milk collected one hour later than the blood samples show a greater tendency towards higher correlation in respect to sugar than do simultaneously collected samples.

6. The difficulty of the satisfactory sampling of blood and milk for comparison studies is emphasized, and an improved sampling method suggested.

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American Dairy Science Association Announcements

ABSTRACTS OF LITERATURE ON MILK AND MILK PRODUCTS

In 1927 the International Association of Ice Cream Manufacturers and in 1931 the International Association of Milk Dealers began the collection, publication and sale of abstracts of literature of interest to their membership. The abstracts have been published approximately on a yearly basis. There was a need for more rapid publication of abstracts, of extending the scope to include all milk products, and to extend the usefulness of the service by expanding beyond individual associations. The obvious manner for accomplishing these objectives was the incorporation of abstracts as a special section of the JOURNAL OF DAIRY SCIENCE

An agreement has been concluded by the American Dairy Science Association, the International Association of Ice Cream Manufacturers, and the International Association of Milk Dealers which has made it possible for the American Dairy Science Association to publish these abstracts in its Journal and for the other two Associations to make available to its members an enlarged abstract service, published monthly. There will be no break in the continuity of the abstract service of these Associations. In view of the previous yearly publication of abstracts a few months will elapse before the abstracts will be entirely up-to-date as it will be necessary to publish abstracts of articles issued since the appearance of Volume 6 of the ice cream abstracts and Volume 4 of the milk abstracts.

Much thought and effort has been given to this abstract service that it might be of greatest value to the membership of the three Associations, to dairy science, and to the dairy industry. It is not expected that the arrangement for the publication of these abstracts or the abstracts themselves will be ideal for everyone but it is expected and hoped that they will serve the greatest possible number in the fields which they include.

Suggestions and criticisms for the improvement of this service will be appreciated by members of the Committee on Journal Management, by members of the Editorial Committee on abstracts, and by the Editor.

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THE SCIENCE PRESS PRINTING COMPANY LANCASTER, PA.

ABSTRACTS OF LITERATURE ON MILK AND MILK PRODUCTS

BUTTER

Arachidonic acid in butter fat. A. W. Bosworth and E. E. Sisson, Dept. of Phys. Chem., Ohio State Univ., Columbus, Ohio. J. Biol. Chem. 107, 489, Nov. 1934

The methyl esters of the fatty acids in butterfat were fractionated and the fraction of B. P. 210°–215° C. at 5 mm. pressure, or C_{20} fraction investigated. Stearic and behenic acids were found but no arachidic could be isolated. The unsaturated acid,—arachidonic—was separated as an octabromide of both the acid and its methyl ester.

CHEESE

The manufacture of low-acid rennet-type cottage cheese. H. L. Wilson and C. S. Trimble, Bur. of Dy. Ind., U. S. Dept. of Agr., Washington, D. C. Issued Oct. 1931. Revised Feb. 1934. U. S. Dept. Misc. Pub. No. 119

A summary of the recommended procedure for making a low-acid rennet-type of cottage cheese follows:

1. Pasteurize the skim milk by heating it to 145° F. and holding at that temperature for 30 minutes before cooling.

2. Add 10 per cent of good starter and 1 cc. of rennet per 1000 pounds of milk. Incubate at 86°–92° F. 4 to 6 hours or until whey acidity is 0.5 per cent. (A less satisfactory method is to add 0.5 to 1 per cent of starter, ¾ to 1¼ cc. of rennet per 1000 pounds and incubate at 72°–76° F. for 8–10 hours.)

3. Fill the jacket with water at 115° F. and cut the curd in cubes. Bring the temperature of the cut curd to 100° F. as rapidly as possible by adding 115° F. water directly to the vat.

4. Cook the curd slowly to 118°–130° F. in 1 to 2 hours. (Keep the water in the jacket 25–35 degrees warmer than the curd.)

5. When the curd retains its original shape after squeezing, draw the whey.

6. Wash the curd two or three times with cold water to remove the whey acid.

7. Trench and drain the curd for an hour and then pack in trays or containers with perforated bottoms and store at 40° F. for at least 4 hours.

8. To each 100 pounds of curd add 1 pound of salt and 60–75 pounds of a mixture of milk and cream containing 15 per cent of butterfat. Store at 30°–40° F. for a few hours before packaging.

Manufacture of cream cheese involving the use of dry skim milk. W. H. E. Reid and H. R. Alley, Dairy Dept., Mo. Agr. Exp. Sta., Columbia, Mo. Mo. Exp. Sta. Cir. 179, July 1934

The advantages of using dry skim milk when manufacturing cream cheese are:

1. Less fat is necessary so that the cheese is more palatable, less sticky, and has better keeping qualities.

2. The life of the cheese is prolonged by the addition of as much as 18 per cent of dry skim milk.

3. The texture of the cheese is improved, producing a smoother and more even spread, and the wheying off of the cheese is reduced.

The formula found to produce the most desirable cheese is as follows:

Butterfat—20 per cent
Dry skim milk—18 per cent
Gelatin—0.4 per cent (280 Bloom test)
Salt—0.75 per cent
Starter—3 per cent for immediate consumption, or 1 per cent if it is to be held in storage 7 to 10 days prior to delivery to the consumer.

CONDENSED AND DRY MILK

Precise determination of calcium, magnesium, and phosphorus in evaporated milk. C. H. WHITNAH AND H. L. ANDERSON, Kansas State Agric. College, Manhattan, Kansas. Ind. and Eng. Chem. (Anal. Ed.) 7, No. 1, p. 46, Jan. 1935

The authors sought to increase the precision of the determinations of these elements, through refinements of manipulation, *i.e.*, good control of ashing temperature and temperatures of ignition of precipitates and the use of a high precision balance (accurate to 10 micrograms).

Details of the procedure and the results of a number of analyses are given. The author concludes that with the precautions observed it is possible to determine the calcium, magnesium, and phosphorus content of evaporated milk with a variation of less than 2 parts per million.

ICE CREAM

Effect of aging treatment on the bacterial count of ice cream mixes. W. S. MUELLER AND R. L. FRANCE, Dairy Dept., Mass. Agr. Exp. Sta., Amherst, Mass. Mass. Agr. Exp. Sta. Bull. No. 314, Oct. 1934.

In a previous study it was found that by aging ice cream mixes for 4 hours at 68° F. the efficiency of the gelatin was increased enough to permit the use of only three-fourths the usual amount without affecting the quality of the ice cream.

From a study of 18 mixes it was concluded that aging of pasteurized mixes for 6 hours at 68° F., whether followed by an 18-hour aging period at 38° F. or not, did not result in a significant increase in the number of bacteria present. Pasteurized mixes held at 68° F. did not show a definite bacterial increase until after the tenth hour.

Aging unpasteurized mixes, as well as pasteurized mixes contaminated after pasteurization, at 68° F. for six hours resulted in a material increase in the number of bacteria present.

A study of the cause of a stale metallic flavor in strawberry ice cream.
P. H. TRACY, R. J. RAMSEY, AND H. A. RUEHE, Dairy Dept., Ill. Agr. Exp. Sta., Urbana, Illinois. Ill. Agr. Exp. Sta. Bull. 407, Nov. 1934

The elimination of copper contamination is the most necessary step in preventing the development of a stale metallic flavor in strawberry ice cream. This off-flavor is associated with the oxidation of the butterfat, as shown by oxidation-reduction measurements made on experimental batches of ice cream. The addition of copper to the ice cream mix catalyzes the oxidation reaction. Ice-cream plant operators need not be troubled with this flavor defect if they exercise proper care in the selection of dairy products and take the necessary precautions to avoid copper contamination of the mix or any of its constituents.

The development of a stale metallic flavor in strawberry ice cream can be retarded by homogenizing the mix at a high pressure, by heating the berries, by soaking the fruit in the mix before freezing, or by increasing the amount of the fruit added or increasing the fiber content of the berries.

Since the off-flavor developed more rapidly in ice-cream mixes to which strawberries were added than in the control mix to which no berries were added, and since the use of the fruit fiber was shown to check the development of the defect, strawberries apparently contain two agents affecting fat oxidation, one serving as a catalyst and the other as a reducing agent. The former is contained in the juice and the latter is associated with the fibrous material. Increasing the citric acid content of the berries did not hasten the development of the defect.

The fact that different commercial pack berries varied in their ability to cause the stale metallic flavor can probably be attributed to the difference in concentration of pack or to the proportion of fiber as well as to the heat treatment given the berries before or after canning. Fruits other than strawberries, such as oranges, lemons, and pineapple, were also found to accelerate the reaction responsible for the off-flavor.

Six of the most common varieties of strawberries grown in southern Illinois were tested for their desirability as a source of flavor in ice cream. These varieties ranked in the following order of preference: Dunlap, Parson Beauty, Gandy, Premier, Gibson, Aroma. The average net weight of Dunlap berries was found to be 24.5 pounds per case of 24 boxes. The average yield per case of 2:1 pack was 4.2 gallons; of 3:1 pack, 3.85 gallons; and 4:1 pack, 3.7 gallons. Either 2, 3, or 4 parts of berries to 1 part of sugar made a desirable pack as far as flavor was concerned. When it was desired to keep the fruit whole, a pack of 3 or 4 parts of

berries to 1 part of sugar or 40 per cent sugar sirup solution was found to be preferable.

Some physico-chemical properties of lactose V. The influence of other substances upon the equilibrium rotation of lactose. B. L. HERRINGTON, Dept. of Dairy Industry, Cornell Univ., Ithaca, N. Y. JOUR. OF DAIRY SCI., Vol. 17, No. 11, p. 701, 1934.

In the investigation of the effect of water concentration upon the equilibrium between the mutarotating forms of lactose, it was found that the equilibrium rotation of lactose was increased about 6.5 per cent by the substitution of glycerol for water as solvent. The equilibrium rotation was also changed by the addition of salts to aqueous solutions of lactose. In most cases, the rotation was increased. The magnitude of the change in rotation depended upon the concentration of both sugar and salt. The results can be explained by assuming that compounds of lactose and salts exist in solution.

Methods of testing frozen cream. H. C. TRELOGAN AND W. B. COMBS, Dairy Dept., College of Agr., St. Paul, Minn. JOUR. OF DAIRY SCI. Vol. 17, No. 11, p. 717, 1934.

In this investigation 5-gallon lard cans were filled with sweet cream testing about 40 per cent of fat and placed in cold storage at –24° F. The fresh sweet cream was sampled and tested before freezing. The cream was sampled when frozen by scraping off any foam and fragments of cream were chipped off with a screw driver. Some of the frozen chips were weighed directly into the test bottle and some were melted before weighing.

The weighing of the frozen chips proved a little more accurate than melting the cream before weighing. An average of 6 analyses on one sample agreed within 0.5 per cent of the test of the fresh cream before freezing.

MILK

The lipids of milk. I. The fatty acids of the lecithin-cephalin fraction. FLOYD E. KURTZ, G. S. JAMIESON AND GEORGE E. HOLM, Bureaus of Dairy Ind., and Chem. and Soils, U. S. Dept. of Agr., Washington, D. C. Jour. Biol. Chem. 106, 717, Sept. 1934

A quantity of lipid material was extracted from sweet cream buttermilk powder, freed from glycerides, and separated into a lecithin-cephalin and a sphingomyelin-cerebroside fraction.

Analysis for the fatty acid content of the former showed the following results: myristic, 5.2 per cent, stearic, 16.1 per cent, arachidic, 1.8 per cent, oleic, 70.6 per cent, and dicostetrenoic (?) 6.3 per cent.

It is surprising that palmitic acid, which is present in milk fat in relatively large quantities is entirely abent in this phospholipid material.

Certain foam producing substances in milk. S. ANSBACHER, G. E. FLANIGAN, AND G. C. SUPPLEE, The Dry Milk Co., Research Lab., Bainbridge, N. Y. JOUR. OF DAIRY SCI. Vol. 17, No. 11, p. 723, 1934.

Certain commercial caseins possess high foaming properties. Such caseins were shaken in a dilute sodium chloride (common salt) solution and the foam producing substance was removed from the casein and was dissolved in the salt solution. About 3½ ounces of the freshly prepared salt solution could be whipped to yield nearly 4 cubic feet of foam. This salt solution contained only 0.07 per cent of salt-free solids which was 13.64 per cent nitrogen, 0.72 per cent phosphorus, and 0.6 per cent sulfur.

This foam producing substance greatly reduced surface tension. Its solution became turbid at 23° C. (73° F.) or above and the solution became colorless at lower temperatures. When freshly prepared the pH was 4.2 but it shifted in 3 days to 5.8 at which pH it formed a flocculent precipitate. By whipping the salt solution, the foam producing substance could be quantitatively removed in the foam. The foam producing solution was altered by aging.

The addition of 5 cc. portions, of this salt solution containing the foam producing substance, to 200 cc. portions of milk produced material increases (from 25 to 62 per cent) in the volume of the cream layer.

Cream flavors and viscosity as affected by the temperature of pasteurization and of the heating medium. J. C. MARQUARDT AND A. C. DAHLBERG, Dairy Dept., N. Y. State Agr. Exp. Sta., Geneva, N. Y. N. Y. Agr. Exp. Sta. Tech. Bull. No. 224, July 1934

For this investigation two 30-gallon vats were used, one being glass lined and the other lined with 18–8 chrome alloy, while in all other respects the vats were identical.

Cream separated from pasteurized milks was free from cooked flavors. Likewise, cream pasteurized at 143.5° F. was usually free from cooked flavors, whereas cream pasteurized at 150° F. usually had a cooked flavor. This flavor was found to be associated more with the fat than with the serum. Cooked flavors apparent two hours after pasteurization sometimes entirely disappeared after 24 or 48 hours' storage at 40° F.

In these experimental vats heating media as high at 210° F. were used when pasteurizing at 143.5° F. without serious flavor effect, but when pasteurizing at 150° F. the temperature of the heating media was a more important factor. When pasteurizing at 150° F. a 180° F. heating medium gave a cooked flavor in 75 per cent of the trials. This flavor always disappeared after storage for 24 hours at 40° F.

Heat-produced films on the walls of the pasteurizing vat had no relation to the development of cooked flavors but did materially reduce the rapidity of heat transfer.

The viscosity of cream was reduced more by pasteurization at 150° F. than at 143.5° F.

The availability of copper in various compounds as a supplement to iron in hemoglobin formation. M. O. SCHULTZE, C. A. ELVEHJEM AND E. B. HART, Univ. of Wisconsin, Madison, Wis. J. Biol. Chem. 106, 735, Sept. 1934

That copper is a necessary supplement to iron in hemoglobin formation is an accepted fact. About 0.005 mg. of Cu per day is enough to produce a distinct response in rats when fed with sufficient iron. However, on a milk diet even greater amounts are ingested and still anemia may result. The explanation seems to lie in the availability of the copper of various compounds. The authors find that the copper of copper caseinate, glycine amide biuret, alanine amide biuret, hemocyanin from *Limulus polyphemus,* and of whole wheat, is readily utilized by anemic rats. Under the same conditions hematoporphyrin is not utilized, even when fed at high levels.

Inhibitors of milk-curdling enzymes. HENRY TAUBER, N. Y. Homeopathic Med. Coll. and Flower Hospital, N. Y. City. J. Biol. Chem. 107, 161, Oct. 1934

Antiproteases of blood serum and egg white are known. The author reports the discovery of a plant antiprotease which exerts a powerful inhibition on the milk coagulating power of proteases. The name, "chymoinhibitors" is suggested for this type of substance. Crystalline urease is a chymoinhibitor and like serum and acetone inhibits the action of pepsin more than that of rennet. It also inhibits the milk coagulating power of trypsin but not its protein hydrolyzing power.

An anemia caused by deaminized casein. ALBERT G. HOGAN AND WALTER S. RITCHIE, Univ. of Mo., Columbia, Mo. J. Biol. Chem. 107, 179, Oct. 1934

When casein is treated with nitrous acid the free amino groups are removed. Rats receiving deaminized casein as the only source of protein survived for only a few weeks. If, when gelatin and gliadin were fed as an adequate protein source, deaminized casein was added to the mixture, the animals became anemic, failed to grow, and died. When deaminized casein was combined with casein in the feed, anemia did not develop.

Further studies on the concentration and chemical nature of vitamin G. LELA E. BOCHER, Dept. of Chemistry, Columbia Univ., New York City. J. Biol. Chem. 107, 591, Nov. 1934

The method for concentrating vitamin G from low lactose whey powder has been previously described by the author. (J. Biol. Chem. 102, 39, 1933.) A further concentration of this vitamin has been accomplished by the use of Lloyd's reagent (specially prepared fuller's earth) with subsequent extraction with dilute pyridine solution.

The resulting product in a dry state is an orange red powder representing a 200 to 300 fold concentration of the vitamin of the whey powder. It carries between 3000 and 3500 units of vitamin G per gram and conforms without qualification to a highly active vitamin G concentrate.

Additional study has confirmed the author's opinion, previously expressed, that vitamin G is itself the water soluble yellow, green-fluorescent pigment of whey, or that the pigment is an integral part of the vitamin.

Rational pasteurization of milk. C. GORINI, Le Lait 14, 924–34, Nov. 1934

The efficiency of pasteurization is usually determined by the number of organisms remaining in the milk rather than the type of organisms. The author believes that pasteurization should destroy all pathogenic organisms and the greater part of the saprophytics; and leave unharmed the more resistant lactics. It should also preserve the high value as a food and be satisfactory for making cheese. These milks should keep for 48 to 72 hours at a temperature of 20 to 25° C.

In the pasteurization of milk at a temperature greater than 70° C. (158° F.) the number of lactics able to survive is greatly reduced. In a study of cultures isolated from commercially pasteurized milk he finds that out of each 100, 98 per cent will survive 63° C. (145.4° F.) for 30 minutes, while at 80° C. (176° F.) only 14 per cent survive. He finds that temperature is not the only factor. It has been demonstrated that the thickness of the film heated is important.

Fat soluble vitamins. XII. The carotene and vitamin A content of colostrum. J. SEMB, C. A. BAUMANN AND H. STEENBOCK, Dept. of Bioch., Univ. of Wisconsin, Madison, Wisconsin. J. Biol. Chem. 107: 697, Dec. 1934

The vitamin A content of milk fat varies seasonally with the diet and also with the breed of the cow. The work reported is the result of an attempt to ascertain the extent to which this factor varies with the stage of lactation. Butter fats were prepared from the milks of Brown Swiss, Ayrshire, Guernsey, Jersey and Holstein cows and the vitamin A and carotent contents determined on these milks, on the 1st, 2nd, 3rd, 7th, and 30th day following parturition.

The carotene and vitamin A content of milk fat prepared from colostrum was found to be from 5 to 15 times that of the fat of ordinary milks from cows of five different breeds on diets relatively low in carotene.

The vitamin A and carotene content decreased rapidly during the first week of milk secretion. Thereafter the decrease was slow. The carotene content of milk fat varies with the carotene content of the feed. However, this is not true during the colostral period and some potent physiological mechanism must enable the body stores of both carotene and vitamin A to be mobilized to an unusual degree. The vitamin A stores of a new-born calf is low and the high vitamin A and carotene contents of colostral enables the young to build up the stores of these dietary factors.

Chemical control of low temperature pasteurization. JEAN PIEN AND JACQUES BAISSE. Le Lait 14: 934, Nov. 1934.

In the method of Schern-Gorli, a colored cream layer is produced in raw milk heated at temperatures below 58° C. (136.4° F.) for 30 minutes, with the addition of a small quantity of a suspension of red blood corpuscles and a colorless layer is produced if heated at higher temperatures for the same length of time. The authors have developed a reagent which has a thermal limit of 67°–68° (152.6°–154.4° F.) instead of 58° C. This reagent is prepared by dissolving 1 gram of casein in sufficient N/10 NaOH to make the solution alkaline, diluting to 100 cc. with H_2O, and adding 1 gram of indigo. Finally add 5 cc. of a 5 per cent phenol solution.

Two drops of this solution are added to 5 cc. of milk and the mixture held for 2 hours, when the cream layer will have formed. Holding at 30° C. decreases the time of its formation. If the milk used has been heated at temperatures of 60°–65° C. (140°–149° F.) for 30 minutes the cream layer will be colored. If heated at 67° C. for 20–30 minutes the cream layer will be colorless. The addition of as small an amount as 5 per cent by volume of raw milk to pasteurized milk produces a double layer in the risen cream. Skimmed milk may be studied by adding thereto a neutral fat to produce a cream layer. Acidity seems to have little effect on the test.

Abstractor's Note: Schern and Gorli (Le Lait 12: 17, 1932) used a suspension of red blood corpuscles for a similar test. Kahn and Klemm (Le Lait 12: 19, 1932) used charcoal and carmine. See Abstracts of Milk Literature (1933) p. 83. The present authors claim greater sensitivity for the test here described.

Cultured buttermilk of the churned variety. A. D. BURKE, Dairy Dept., Alabama Polytechnic Institute. Milk Dealer, Vol. 24, No. 3, p. 72, December 1934

Three methods of producing cultured buttermilk are described; the churning method, the granule or churned cream method, and the drop or pellet method.

In the first method, milk containing 1.5 to 2.0 per cent fat is pasteurized at 180° F. for 30 minutes, cooled to 68–72° F., and cultured in the usual

manner. When properly ripened, the curd is broken and the buttermilk is churned or agitated until the fat particles appear about half the size of wheat kernels. Two separate batches of cultured milk are sometimes prepared, one containing 4 per cent of fat, and the other consisting of skim milk. In churning only the whole milk, and mixing with the skim milk afterward, the tendency toward foaming is minimized.

The granule or churned cream method consists of churning cream with a fat content of about 30 per cent until granules of the proper size appear, drawing off the buttermilk, washing the butter particles with cold water, chilling them, and adding them to cultured buttermilk.

The drop or pellet method is given in three steps:

(1) Sweet cream or butter of the finest grade is oiled off by heating in a container placed in hot water. Sufficient time is allowed for the pure butter oil to float to the surface.

(2) A tinned copper trough with holes punched in the bottom, a single row the full length, is prepared. The holes should be small, about the diameter of a large pin shank, to permit the butter oil to drip through in small drops.

(3) The trough is suspended over a vat of cultured buttermilk, properly prepared, and cooled to 45 to 50° F. The butter oil drops, drop by drop, into the cold buttermilk, with sufficient of the buttermilk being maintained. The drops of melted oil flatten and solidify immediately when they strike the cold milk. They remain well suspended and evenly distributed, and produce a very pleasant buttery sensation of rich palatability.

Butter color may be used in all three of the methods.

High potency vitamin D milk. C. I. Post, Mgr. Vitex Dept., National Oil Prod. Co., Inc., Harrison, New Jersey. Milk Dealer, Vol. 24, No. 3, p. 39, Dec. 1934

A brief article pointing out the special service which dairies putting out vitamin D milk with added vitamin D concentrate, may render to physicians, by being able to supply, in accordance with his directions, milk having any desired vitamin D content up to 1500 U. S. P. units per quart.

This service, being highly special, is not restricted as to price, and permits the dairyman to profit by the increasing interest in vitamin D therapy on the part of the medical profession.

The manufacture of whipped cream using dry skim milk. W. H. E. Reid and W. C. Eckles, Dairy Dept., Missouri Agr. Exp. Sta., Columbia, Missouri. Missouri Exp. Sta. Cir. 180, July 1934

The advantages of adding dry skim milk to cream that is to be whipped are:

1. Reduces drainage.
2. Improves body of the whipped cream.
3. Improves the flavor and nutritive value of whipped cream.
4. Some creams that are undesirable for whipping purposes, are made whippable by the addition of skim milk powder.

From 4 to 6 per cent of the skim milk powder should be added in the form of a paste prepared by mixing with a portion of the original cream. This paste should be added to the cream after it has been cooled and pasteurized. The treated cream should be aged at 40° F. for 12 to 24 hours before whipping. If sugar is added it is best done at the time of adding the skimmilk powder.

Costs and returns in operating milk and cream collection routes in Maine. GEORGE F. DOW, Maine Agr. Exp. Sta., Orono, Maine. Maine Exp. Sta. Bull. 374, Sept. 1934

This study represents an analysis of the costs and returns for collecting milk and cream on 90 collection routes during the year ending June or July 1932. A summary of costs and returns in operating these routes is given in the table.

TABLE 1

Summary of costs and returns in operating 90 milk and cream collection Routes during 1931–1932

	NUMBER OF ROUTES	AMOUNT PER ROUTE	AVERAGE PRICE	VALUE PER ROUTE	PER CENT OF TOTAL VALUE
Costs for route:					
Man labor	90	1,998(hrs)	$.22	$439.59	35.9
Use of motor truck	90	15,246(mi)	.05	742.59	60.6
Horse labor	41	248(hrs)	.11	27.27	2.2
Hired hauling	15			15.46	1.3
Total cost	90			$1,224.91	100.0
Miscellaneous income	28			$ 44.22	3.6
Net cost for hauling milk and cream	90	5,173(cwt)	$.23	$1,180.69	96.4
Total returns for hauling milk and cream	90	5,173(cwt)	$.34	$1,771.96	
Net returns	90	5,173(cwt)	$.11	$ 591.27	
Returns for man labor*	90	1,998(hrs)	$.52	$1,030.86	

* "Returns for man labor" represents total returns after deducting all collection costs except man labor, and thus represents the amount received by the motor truck operator in payment for his labor in collecting milk and cream.

Volume of milk and cream hauled per mile and miles per trip accounted for 83 per cent of the total variation in cost per hundred-weight for collection. Elimination of competition in hauling might therefore appreciably reduce the hauling cost.

Unimproved roads proved to be an important factor in increasing costs. On collection routes where less than one-fourth of the mileage was found to be improved roads, a saving of 4.7 cents per hundredweight could be made if the roads were all improved. This does not allow for the saving in time to the farmer who has to transport his milk to the hard road when traveling is difficult.

An economic study of the collection of milk and cream in Maine. GEORGE F. DOW, Maine Agr. Exp. Sta., Orono, Maine. Maine Exp. Sta. Bull. 373, August, 1934.

Important changes in the collection of milk and cream in Maine from 1928 to 1932 have been studied. In 1928 much of the milk was delivered three times a week but by 1931 practically all the milk was being delivered daily. Cream deliveries increased only slightly—from 2.6 to 3.0 times per week on the average.

From 1928 to 1933 the average hauling distance was approximately tripled as a result of the closing of many local plants. This in turn has resulted in an increase in the quantity of milk and cream gathered on collection routes and a decrease in the amount delivered by individual dairymen.

From 1930 to 1931, 22.4 per cent of the milk was delivered by dairymen, 76.2 per cent by hired collectors, and 1.4 per cent by railroad. In the case of cream the proportions were about the same except that the railroads received a slightly higher percentage of the business. Hired collectors hauled milk about 20 per cent more economically than did individual dairymen for distances of less than 3 miles and 55 per cent more economically for distances of 6.0 to 8.9 miles. Exchange hauling resulted in reduced delivery costs of over 50 per cent when the exchange was made by three or more dairymen.

On three-fourths of the collection routes the hauling charge on milk was the same for long hauls as it was for short hauls. For individual farmers, however, the average hauling cost increased from 27 cents for distances of less than 3 miles to 67 cents for distances of 6 to 8.9 miles, while the average cost of hauling cream increased from 79 cents to $1.57 per hundred pounds.

Horses were used for delivery by 15 per cent of the dairymen. The cost per mile was three cents greater with horses than with motor vehicles.

The concentration of the dairymen was an important cost factor. The hauling cost for the concentrated producers averaged 29 cents per hundred pounds for milk and 68 cents per hundred pounds of cream, as compared with 41 and 95 cents respectively for the dairymen in less concentrated areas.

Increased volume resulted in decreased hauling cost in the case of delivery by the individual dairymen, but in the case of the collection route the producers volume did not influence the hauling cost.

Undulant fever (Brucellosis) with reference to 148 cases encountered in and about Dayton, Ohio. W. M. SIMPSON. Jour. Ind. St. Med. Assn. 27: 564, Dec., 1934.

In a comprehensive discussion of undulant fever in man, as reported by other investigators and as observed by the author in 148 cases, the writer concludes that "there appears to be but one logical method for preventing the transmission of milk-borne infection to human beings and that is by pasteurization."

An x-ray study of nutritional deviations. T. WINGATE TODD. Jour. Home Econ. 26: 605, Dec., 1934.

Roentgenographic studies have shown that all children require a quart of milk a day to insure the calcium intake necessary for optimum growth and well-being, and that pregnant and nursing women need a quart or more to take care of the demands of the fetus and prevent depletion of their own calcium supply.

The author points out that milk, yielding 325 calories to the pint, is not in itself a fattening food; and that a diet containing adequate amounts of protective foods is more important to good health than is one rich merely in energy-producing foods.

Some ingestion of milk stimulates the flow of gastric secretion, and the amount of fluid in the stomach is doubled in a few minutes, consumption of milk satisfies the appetite. Milk should, therefore, be given to children between meals as well as with meals. When taken with meals, the solid foods induce relatively less gastric secretion. Cloying of the appetite is more pronounced with buttermilk than with whole milk, as shown by the roentgenoscope.

Undulant fever control in Washington Co., Maryland. W. R. CAMERON AND M. WELLS. South Med. Jour. 27: 907, Nov., 1934.

Use of the Huddleson rapid macroscope agglutination test for the diagnosis of Bang's disease in herds supplying milk to Hagerstown, Maryland, is discussed in this paper. Cases of undulant fever were traced to those herds in which more than 20 per cent of the animals were infected. Successful efforts to eliminate the disease from the herds were accompanied by a significant decrease in the number of cases of undulant fever. The Huddleson method is believed to be a "simple and practicable method whereby a health officer may rather quickly determine the possible source of a particular case of undulant fever." The authors further believe that examination of milk serum for diagnosis of Bang's disease and the elimination of diseased animals from herds is an effective method for control of undulant fever wherever pasteurization is impracticable.

Factors influencing the utilization of calcium and phosphorus of cow's milk. J. H. HESS, H. G. PONCHER AND H. WOODWARD. Am. J. Dis. Child. 48–1058, Nov., 1934.

Metabolism studies on an infant receiving 100 cc. per kilogram daily of whole cow's milk treated by the base exchange process to lower the curd tension, show that better utilization of the calcium and phosphorus of the milk results than when ordinary milk is used, although there is a reduction in the amount of these two minerals as a result of the base exchange process.

It is believed that the size of the curd, the state of the calcium and the reaction of the ash must be influenced favorably in order to secure more efficient utilization of the minerals.

MISCELLANEOUS

Alcohol-gasoline engine fuels. HARRY MILLER, Idaho Agr. Exp. Sta., Moscow, Idaho. Idaho Agr. Exp. Sta. Bull. No. 204, June, 1934.

The blending of alcohol with gasoline was brought to the attention of the American public by the low prices for agricultural products. Ethyl or grain alcohol may be produced from sugar or substances that can be converted into sugar and from ethylene gas. Alcohol may be used as a fuel in internal combustion engines either in the pure state or in conjunction with petroleum fuels, such as gasoline. Anhydrous or absolute ethyl alcohol will mix with gasoline in all proportions. Commercial alcohol (95 per cent purity) will not mix with gasoline unless it constitutes at least 50 per cent of the mixture. However, by adding blending agents, such as the higher alcohols, commercial alcohol can be made to blend with gasoline in any proportion. This can also be accomplished by using a double bowl carburetor connected to separate fuel tanks.

Tin is corroded more by alcohol than by gasoline; iron, lead and aluminum being affected less. Zinc and steel are affected by neither.

There is no danger of alcohol separating from gasoline due to the addition of such amounts of water as are likely to get into the fuel tank by condensation, or by filling the tank during a rain, or by absorption of moisture from the atmosphere.

There is no danger of corrosion from the products of incomplete combustion of a mixture of alcohol and gasoline. No difficulty has been experienced in starting motors when using alcoholic blends. The addition of one-half per cent of oleic acid to the lubricating oil increases the efficiency of such fuels.

The amount of carbon monoxide formed when alcohol is used is reduced about 75 per cent of what is formed from gasoline. The lessened amount of carbon monoxide found is desirable from a hazzard standpoint and results in the liberation of more heat, as one pound of carbon oxidized to

carbon monoxide releases 4,360 B.T.U. compared with 14,600 B.T.U. when oxidized to carbon dioxide. This offsets any difference there may be in the caloric value of gasoline and alcohol.

If 20 per cent of our motor fuel were alcohol derived from agricultural products it would create a market for 2,200,000,000 bushels of corn (1928 crop was 2,500,000,000 bushels) or 113,000,000 tons of potatoes (1928 crop was 14,000,000 tons).

Dry ice would become an important by-product in the manufacture of alcohol from agricultural products. This refrigerant could be made for 0.5 to 0.75 cents per pound. The protein and carbohydrate residue also could be utilized for feeding dairy cattle.

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The American Dairy Science Association was organized to advance the general welfare of the dairy industry, especially by the improvement of dairy instruction by the stimulation of scientific research in all phases of the subject and by improvement in methods of conducting extension work.

Membership shall consist of two kinds: (1) active, (2) associate.

The qualifications for membership in the two classes are as follows: (a) Any person is eligible to active membership who is formally announced by an Agricultural College, or Experiment Station, or by the Bureau of Dairying of the United States Department of Agriculture as an instructor, extension worker, investigator, or administrative officer connected with the dairy industry, or (b) anyone filling a position of responsibility connected with the dairy industry and who has had a college or University training in technical science, or anyone filling a responsible position in the industry of a professional character requiring a technical knowledge of dairying of a high order.

Any person is eligible to associate membership who is regularly enrolled in a collegiate course in a college of Agriculture and who is specializing in dairying. Associate membership is attained by election to membership in a local chapter of *The American Dairy Science Association.*

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